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The Committee Organization of the Society

THE work of the Society is carried out largely through committees working under the direction of the Council in accordance with the Constitution and By-Laws adopted by the membership. Figs. 1 to 5 show these committees and indicate their organization and the procedure followed in adopting reports.

In several of these charts the Society Business Session or Meeting has been given the status of a separate committee. This has been done as the Constitution states that an act of the Council that shall have received the expressed or implied sanction of the membership at any subsequent Society Meeting shall be deemed to be the act of the Society and shall not afterwards be impeached by any member.

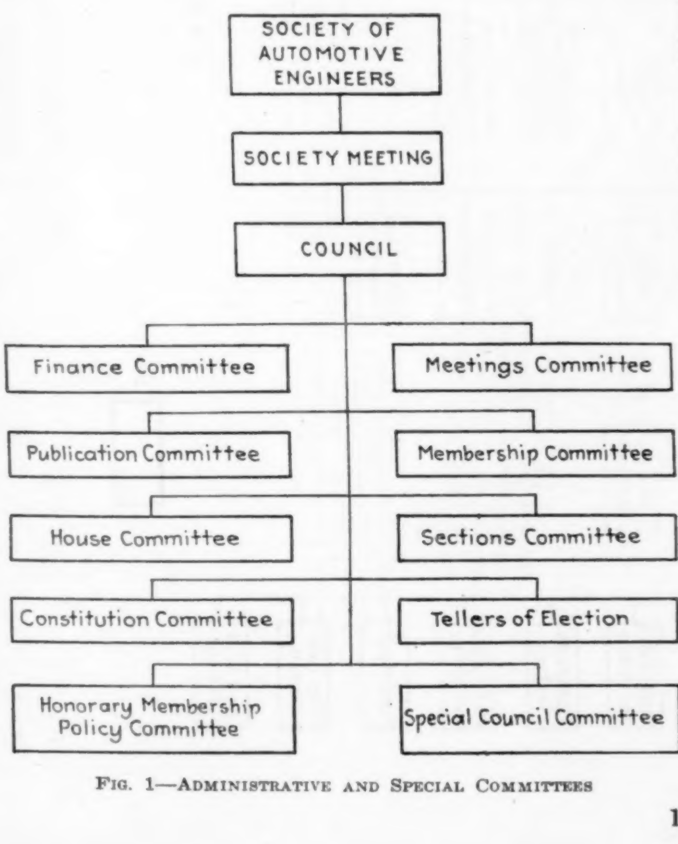


FIG. 1—ADMINISTRATIVE AND SPECIAL COMMITTEES

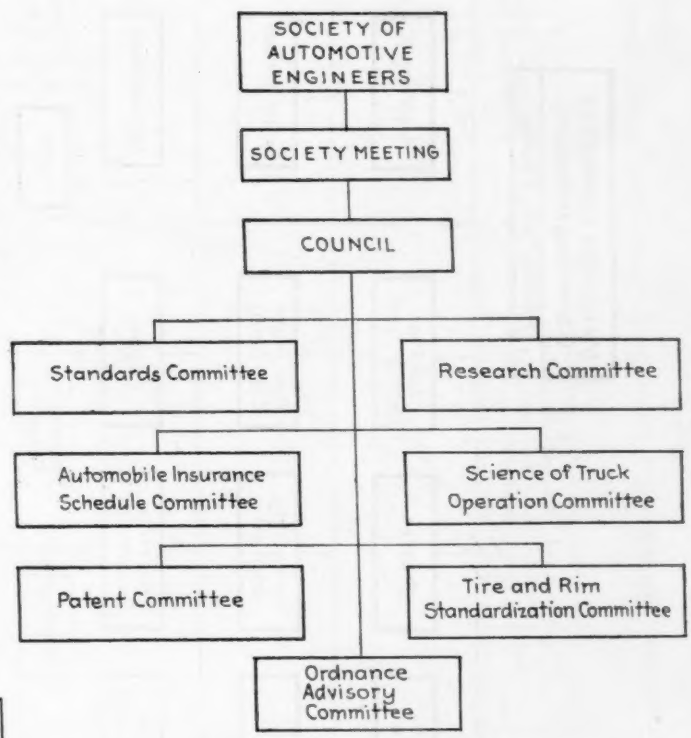


FIG. 2—STANDARDS AND PROFESSIONAL COMMITTEES

The Council may also order the submission of any report to the membership by letter ballot. As the Standards Committee work is of vital interest to the members, the Council has ruled that all Division reports approved at a Society meeting shall be submitted by letter ballot to the voting members of the Society.

ADMINISTRATIVE COMMITTEES

Seven administrative committees are appointed annually by the President of the Society within 30 days after taking office from the individual membership of the So-

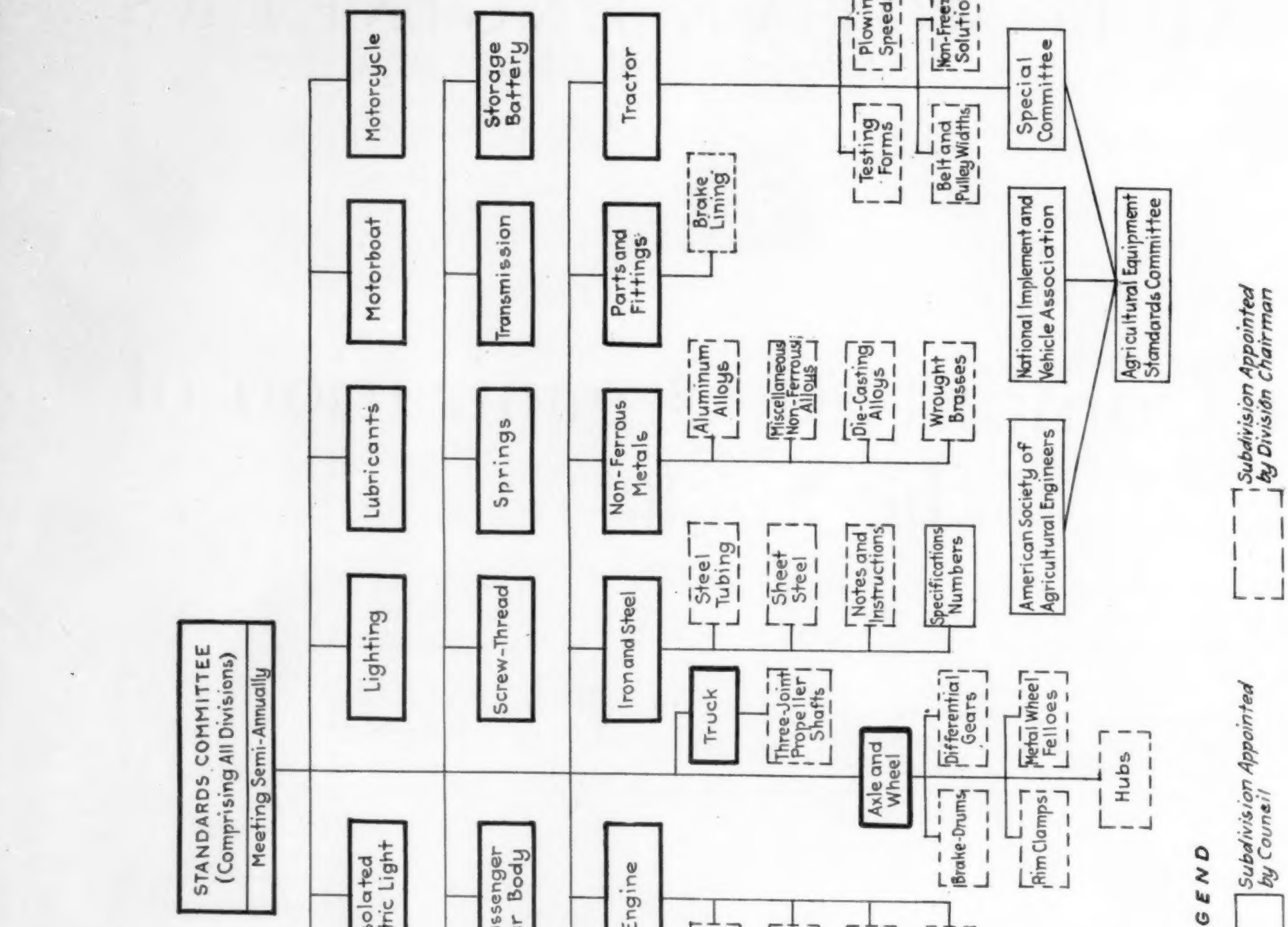


FIG. 3—ORGANIZATION OF THE STANDARDS COMMITTEE OF THE SOCIETY

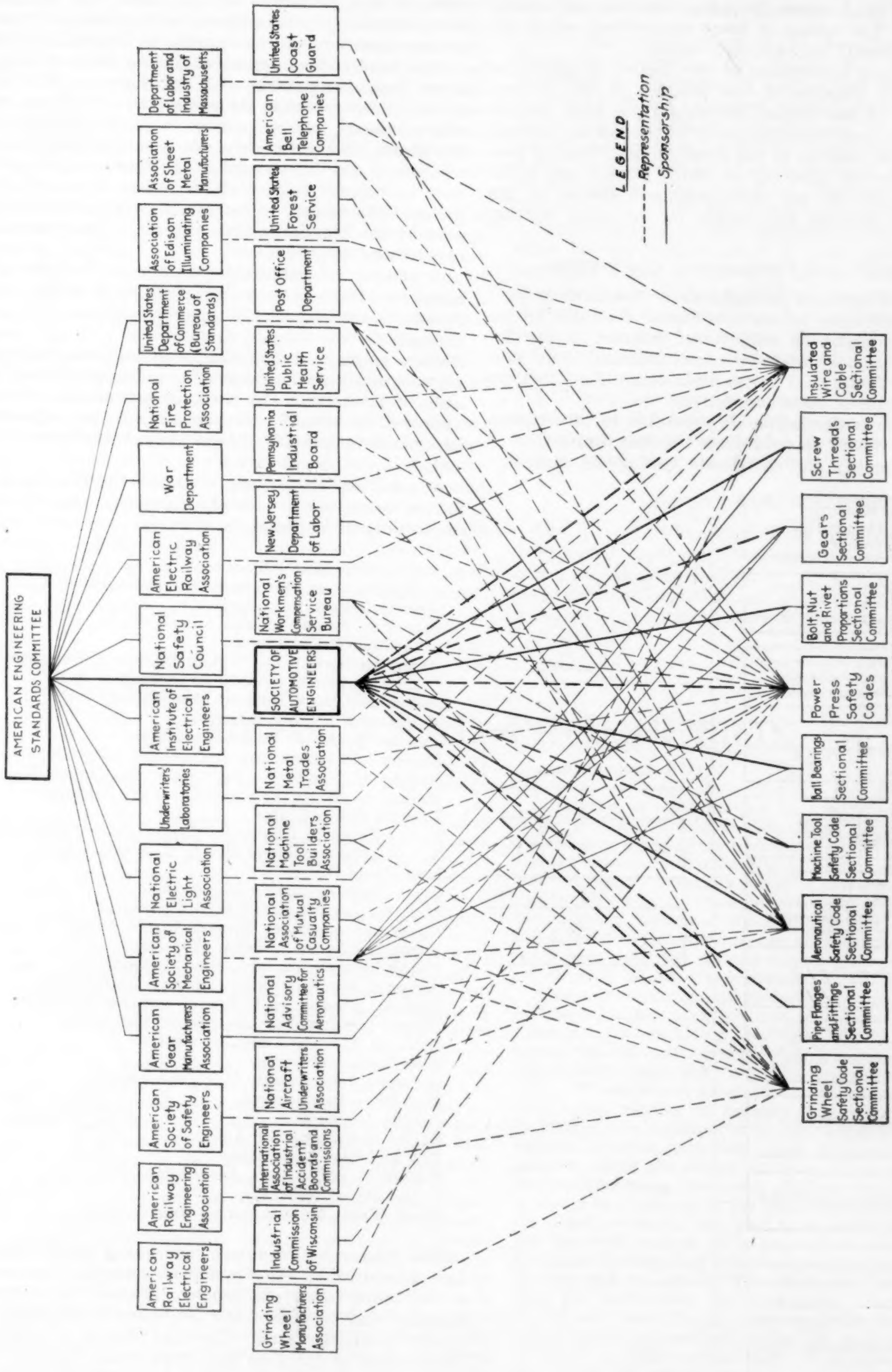


FIG. 4—RELATION BETWEEN THE AMERICAN ENGINEERING STANDARDS COMMITTEE AND THE VARIOUS NATIONAL ENGINEERING ORGANIZATIONS

ciety, the chairmen thereof being designated by the President. Fig. 1 shows the administrative and special committees. The names of these committees, which report to the Council, indicate their duties.

A Nominating Committee of the Society is appointed each year and consists of one Member of the Society elected prior to the Annual Meeting from each Section of the Society and three Members of the Society elected at the Business Session of the Semi-Annual Meeting preceding the Annual Meeting at which officers are to be elected. No two of the three members elected at the Semi-Annual Meeting can reside in the same Section district.

Standards and Professional Committees

The Council appoints annually such standards or professional committees as are considered desirable to investigate and report on subjects of interest to the Society. The chairmen of such committees and their subdivisions are designated by the President. Fig. 2 shows the organization of these committees.

The Standards Committee is appointed to investigate, consider and report upon subjects the standardization of which will simplify and coordinate automobile engineering practices. The Committee consists of 26 Divisions with a total personnel of over 270. To facilitate the work Subdivisions are appointed consisting of members or non-members of the Standards Committee. Of the active Subdivisions appointed during 1921, 39 consist of more than one member and are shown in Fig. 3. The Subdivisions report to their respective Divisions, the Division reports having to meet with the approval of the Standards Committee as a whole before being submitted at Council and Society meetings. The work of the Standards Committee is carried on by the Standards Department of the Society under the Supervision of the Chairman of the Standards Committee and the General Manager of the Society.

A special committee, the members of which are also members of the Tractor Division, shown in Fig. 3 as the Special Committee of the Tractor Division, is appointed annually by the Council to cooperate with the American Society of Agricultural Engineers and the National Implement and Vehicle Association in the adoption of standards of interest to the three organizations. Standards approved by two of the three cooperating organizations become automatically "Agricultural Equipment Standards."

In addition, the Society, through the Standards Committee, is in touch with the following organizations in connection with standards matters of common interest.

Air Service, War Department
American Gear Manufacturers Association
American Petroleum Institute
American Society of Mechanical Engineers, Committee on Steel Roller Chains
American Society for Testing Materials, Subcommittee X on Automobile Steels of Committee A-1
Automobile Body Builders Association
Automotive Electric Association
Automotive Metal Wheel Association
Bureau of Construction and Repair, Navy Department
Bureau of Standards, Department of Commerce
Bureau of Steam Engineering, Navy Department
Electric Power Club
Forest Products Laboratory, Department of Agriculture
Gas Engine and Farm Power Association
Iowa State College
Lamp Standardization Exchange
Lock Washer Manufacturers Association
Motor and Accessory Manufacturers Association
Motor Transport Division, War Department
Naval Aircraft Factory, Navy Department
National Advisory Committee for Aeronautics
National Association of Engine and Boat Manufacturers
National Automobile Chamber of Commerce
National Electric Light Association
Ohio State University
Ordnance Department, War Department
Post Office Department
Purdue University
Rubber Association of America
Tire and Rim Association
Trailer Manufacturers Association
University of Nebraska
Wood Wheel Manufacturers Association

The Research Committee, consisting of 10 members, was appointed by the Council to supervise the analysis of the more important problems before the automotive industry and to obtain the necessary fundamental data to aid in solving them. The organization of a Research Department to carry on this work under the supervision of the Research Committee has been recently authorized by the Council.

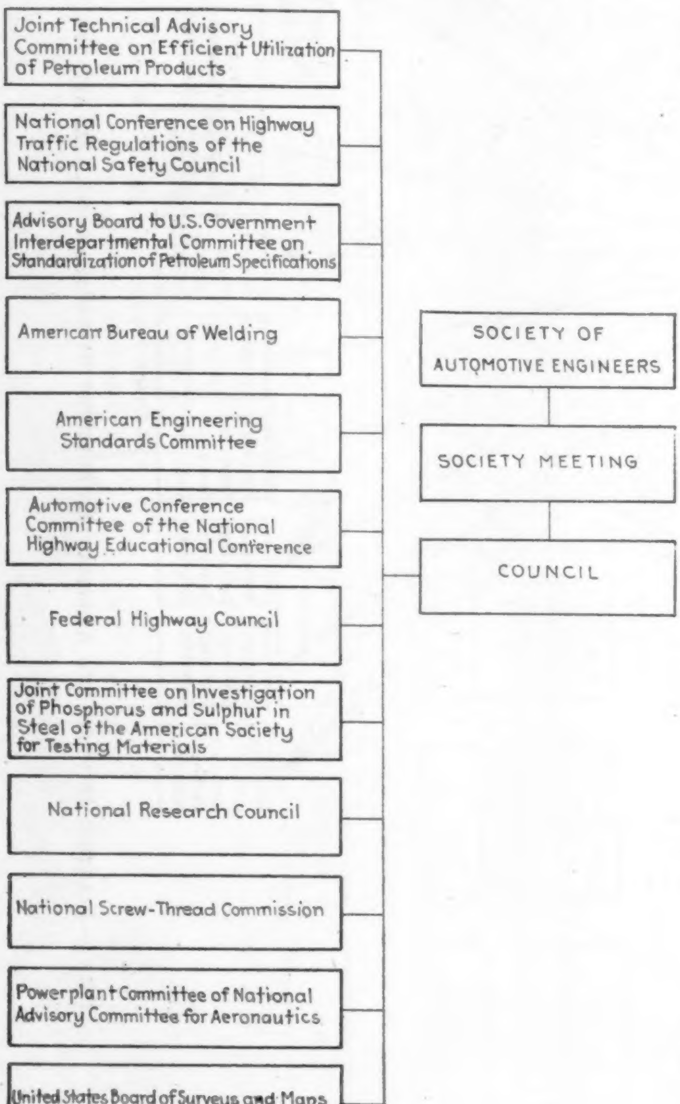


FIG. 5—SOCIETY REPRESENTATION ON NATIONAL ORGANIZATIONS AND COMMITTEES

The Automobile Insurance Schedule Committee was appointed by the Council in 1918 to cooperate in a technical advisory capacity with the Insurance Committee of the National Automobile Chamber of Commerce and the Underwriters Laboratories in formulating an improved method of establishing automobile insurance ratings based on the relative merits of mechanical constructions instead of the now discarded method based on prices. The Committee is also the arbitrating body for decision in disputed engineering matters pertaining to the schedule. There are nine members on this Committee.

The work of the Committee on the Science of Truck Operation which has five members is to compile truck operating statistics. The committee also keeps in close touch with the road impact-test work of the Bureau of Public Roads of the Department of Agriculture inasmuch as highway construction and maintenance are of vital importance.

The Patent Committee, consisting of three members, was recently organized to serve in an advisory capacity in standards matters involving patents.

The Tire and Rim Standardization Committee was established to determine upon a policy under which the Society will carry on tire and rim standardization in cooperation with The Rubber Association of America and the National Automobile Chamber of Commerce.

The Ordnance Advisory Committee cooperates with representatives of the Army in matters involving the design and operation of automotive equipment developed and used by the United States Ordnance Department. The present Committee has eight members.

American Engineering Standards Committee Sectional Committees

With the organization of the American Engineering Standards Committee the Society has become directly interested in 10 Sectional Committees appointed in accordance with the rules and regulations of the American Engineering Standards Committee. In four cases the Society is a sponsor for the Sectional Committee. Fig. 4 shows the different societies cooperating in the Sectional Committees of the American Engineering Standards Committee in which the Society is interested.

Representation on the Sectional Committees is indicated by the broken and full lines connecting the cooperating organizations with the Sectional Committees. Sponsorship, including procedure insofar as the approval of Sectional Committee Reports is concerned, is indicated by the full lines connecting the Sectional Committees with the cooperating organizations and those in turn with the American Engineering Standards Committee. It will be seen that many cooperating organizations are not members of the American Engineering Standards Committee, but merely represented on the Sectional Committees in which they are interested.

Society Representatives

The Society is represented by members appointed by the Council on several organizations of national importance, as indicated in Fig. 5. In this way the work of other national organizations of interest to the members is coordinated with the work of the Society.

DESIGN AND PRODUCTION

A CONSIDERABLE amount of attention has been devoted in recent times to the close connection that exists between design and production, but it is still very evident that this important relationship, while upheld by most engineers in theory, does not even now materialize sufficiently in practice. There are various reasons for this. Many products, for instance, involving expensive patterns, jigs, tools, etc., were originally designed at a time when the outlook on this subject was not so clear as it is at present. In other cases designs are put through, often of necessity, in such a way, and with such a time limit, that it is inevitable that production matters do not receive adequate attention. It is, however, important to urge the utmost possible consideration of all problems connected with manufacture in the early stages of the design.

Manufacturing considerations should commence with the very first layout on the drawing-board. It is not sufficient that the machine should be broadly schemed out first, and its manufacture considered in relation to the structure as thus conceived. It is scarcely necessary to point out that simplicity or complexity in production is settled just as much by the principles underlying the original layout as by the subsequent designing and arranging of details and dimensions. A careful survey of the design of almost any engineering product, whether this be of simple or complicated nature, inevitably leads to the conclusion that manufacturing methods have been planned inadequately in the original laying out of the design. This seems particularly unfortunate when it is borne in mind that modern machine-tools and manufacturing methods have now reached a stage where they offer to the well-versed and skillful designer opportunities of producing at an extraordinarily low cost; so much so, that even the cheapest materials in many articles of commerce, given a fair manufacturing design, will form the largest item in the total cost of production of the completed article.

In the case of other designs the production engineer labors in the face of tremendous difficulties. He is called upon to manufacture parts of unnecessary complication, involving expensive operations that have to be performed in an awkward manner, and is generally hampered in every possible way. Particularly glaring examples were, of course, furnished in the design of certain of the munitions used during the war, but here, of course, the urgency with which many of the designs were produced and the necessity for immediate output outweighted all other considerations.

Although bad design for production becomes, as a rule, most evident when the parts go into the machine-shop, and consideration for machining operations is of paramount importance, yet the pattern-shop, foundry and drop-forging or blacksmith's shop must not be overlooked in the drafting-room. Where this is a department of reasonable size dealing with a fair number of designs, it is evident that, until all draftsmen are equipped with the necessary knowledge of modern practice, somebody must be appointed capable of superintending the design of every detail part, solely from the manufacturing viewpoint. Before the drawing is issued it should be examined by the production expert, not only from the broad viewpoint of a part to be manufactured, but from the narrower outlook of a part to be manufactured by a particular factory, due consideration being given to the number required, the quality of workmanship and the plant available for performing the operations. Such an individual should have authority to reject unsuitable designs, and every effort should be made to render his work a valuable asset as a reducer of production costs. Superintended in this way, the design of practically any part or component can be modified in a way that results in considerable saving.—*Engineering Production* (London).

Education for Highway Transport

By Charles J. Tilden[1]

Semi-Annual Meeting Paper

THE author discusses the kind of college education that should be offered to those who expect to become engaged in highway transportation by motor truck, with reference to organization, regulation and operation on a large scale. Stating that the main factors of such an education fall naturally into the three divisions of the highway, the vehicle and the business, these are considered with regard to what topics might be presented profitably to college students under these respective heads, the subjects and the factors that govern their desirability being commented upon in general terms.

The main principle which should be borne in mind in educating men for the motor-transport business and the main value of such an education lie in the intellectual development and ability to analyze critically, which give the student mastery over new situations as they arise, and ready adaptability to the needs of any given business situation.

A GREAT business is being born. One of the oldest means of travel and transportation has come suddenly into the most prominent place in the Nation's economic life. With the increasing demand in the past few years for means of collection and distribution of commodities of all kinds the highway has suddenly taken a place fully as important as that of the railroad in this phase of human activity. The rapid development of the motor truck and the passenger car has, of course, made this possible, and our 2,500,000 miles of highways offer almost limitless possibilities for commercial development in the way of motor transport.

It is the business of schools to prepare future citizens to take their part in the organized work of the Nation. I have been asked to discuss the college education which should be offered to those who expect to engage in highway transport, with special emphasis upon the necessity of educating men who upon completion of their courses can organize, regulate and operate truck transport on a large scale. That is something of a task. It would be a very large order for any college or university. Suppose the Congress, in providing for the Military Academy at West Point, should instruct the superintendent to educate men who upon completion of the course would be in a position to take command of a brigade in the field and assume all the other duties and functions of a brigadier general.

The successful operation of truck transport on a large scale is no different from that of any other big business except that there is little or no past history or experience to serve as a guide. It calls for an unusual degree of initiative and foresight. It involves duties and responsibilities which can be performed only by men experienced in business organization and management, and experience is one thing which our colleges have not yet been able to teach. The college course does not aim to do more than fit men in the most efficient manner to begin their experience. The term "commencement," denoting the completion of the four years of college work, is used advisedly. It marks the real beginning of life's work, and a college man cannot be ready for inaugurating and carrying on a great business until his college work has been rounded out and tempered by some years of actual contact with business life.

What the Colleges Should Teach

There are, however, certain phases of instruction in the field of highway transport that can be offered profitably to the college student. They should be planned to put him in the way of study and thought along the lines of his expected life work. A well-rounded course which commands a large part of the student's time during his four years in college may well be based on the important functions of the highway in serving the community's transportation needs. Except in its strictly technical phases, such as highway location and construction, it is not necessary to limit this study to engineering schools. Students of business administration and other branches of the arts and sciences will find much in it of interest and profit.

In blocking out college courses in highway transport the main factors fall naturally into three principal divisions, the highway, the vehicle and the business. Let us consider these in order and see just what topics might profitably be presented to college students under the respective heads. The highway is such a universally accepted fact of life that we pay singularly little attention to it. It is, however, an objective fact which well repays study. It has an interesting history. It is based on fundamental laws of human needs and desires which bring out the community life in a most interesting manner. What the highway is, the relation it bears to the community and the individual, the laws under which it is established and maintained and the nature of the structure that is necessary to enable it to perform its functions properly are questions that cover a broad range in engineering, law and social science. The economic question of the cost of building roads and the best ways of financing this cost and providing for maintenance are also topics worthy of study by every citizen who must at some time or other vote on these questions. The regulation of traffic both in city streets and in other less congested highways is a science which in some of its phases is as exact as the demonstrations of Euclid, but has always the uncertain element of human action which adds greatly to its interest as a study. In this connection it may not be amiss to quote from a recent letter from the chief engineer of one of the large motor-car companies.

> When a man travels from his home to some nearby point and falls into a chuck-hole and breaks the spring or some other part of the car, he immediately gets in touch with the dealer or factory and tells what he thinks about the poor materials which they allow to enter into the car, but never thinks of calling up the road commissioner and complaining of the condition of the road. As a matter of fact, the average man does not know anything about roads. He probably would not know whom to call up if he wanted to complain about the road.

This situation has its basis, of course, in the fact that the car belongs to the individual. He has bought and paid for it and either loves or hates it, according to his frame of mind. The road, on the other hand, belongs to everybody, and hence to nobody. It is no particular con-

[1]Director, highway and highway transport education committee, Department of Agriculture, Washington.

cern to the car owner that there are holes in it, but it is of vital concern to him if anything happens to his car.

The prospective manager of a large highway-transport business should have an intimate knowledge of the motor car as an engineering unit. Here again there are many features of general interest that any well informed citizen might be expected to know. It is astonishing, in connection with the rapid increase of motor vehicles, both passenger and freight, how general the knowledge concerning them has become. School children who cannot pass history tests or do examples in the rule of three can discourse knowingly of spark-plugs, gasoline mileage and the relative value of different makes of car. The car, however, is an extremely complicated and intricate mechanism, a structure whose development has followed definite lines, and the difficulty of suggesting a college course on the subject would be to know where to stop and what to leave out. The fundamentals of the gas engine in both theory and practice should, of course, be thoroughly taught. The details of the construction and operation of different makes of car could be embodied in a laboratory course as exacting and with as high an educational value in mental training as any of the so-called pure sciences. One has only to think for a moment of what is under the hood to realize what wonderful exercises there are in dissection and synthetic coordination in the study of a motor truck. A considerable number of schools are now offering practical and theoretical courses in automotive engineering and this number might well be increased.

Instruction in the sound business principles which underlie all commercial operation is most important. In discussing the cause of failure of some recent motor-transport ventures a well-known operator in New York City wrote as follows:

> Motor-truck freight rates are based on the cost of truck operation and although over $2,000,000,000 is invested in motor trucks their operators are almost completely ignorant of their true operating cost.

This is from a man who has given considerable constructive study to the whole matter. It contains much food for thought on the part of those who are interested in the operation of motor vehicles as a business for legitimate profit. It should also be a challenge to our schools and colleges, for it points out where ignorance lies. Of course, all business is based on sound economics and fundamental courses in economics should constitute an important part of all business training. After this preliminary study, specialized courses could very well be offered dealing particularly with motor-vehicle problems. The difficulty with which we are confronted at once is the lack of reliable fundamental data. There is great need for research and for careful coordination and organization of existing facts with critical examination of the published material to determine how much of it really is fact. There is much more to the cost of operating a truck than simply the expense of gasoline and oil. The surface of the highway over which it must operate has a decided influence on operating costs. A prominent professor of economics in one of our large universities said recently that it would take five years to systematize and arrange the existing material in regard to highway transport so that a satisfactory undergraduate course of study could be developed from it. This is rather an appalling view to take, for long before the five years were up most of the material would be out-of-date.

The prime object of a college course is, however, not to give information, but to develop the student's thinking power and put him in the way of critical study of conditions as he finds them. There is probably not a college graduate of five years standing in the country who uses, to any great extent, merely the facts that he acquired in college. Mental power, intellectual development and ability to analyze critically constitute the main value of those four years. It does not matter so much what a student thinks about, or whether the material that he is studying is likely to be out-of-date in a short while, as long as he thinks straight, hard and continuously. Only in this way can he gain the mental power that will give him quick mastery over new situations as they arise, and ready adaptability to the needs of a business situation. This is, after all, the main principle that should be borne in mind in laying down a college course designed to train men for the motor-transport business.

But the college man must be first of all a citizen. He must understand the things I have indicated and many others in their relation to community needs. It is not well to give such a large proportion of the student's time to specialized subjects that the more general topics which enter into a broad education are sacrificed. A thorough appreciation of the fundamentals of history, training in expression, both written and spoken, some knowledge of at least one language other than his native tongue and an insight into the great fields of chemistry, biology, geology and physics, are part of the proper equipment of the educated useful citizen. He should be able to deal pleasantly and effectively with his fellow-men, understanding the principles of teamwork and cooperative effort. If he is able to get some of this on the football field he will have a training such as no course in the classroom can possibly give.

CORRECT ADDRESSES OF THE MEMBERS

A FORCE is maintained in the offices of the Society at New York City whose sole duty is to keep the addresses of the members uptodate. A large number of changes of addresses are received each week by this department, and these are made promptly. In numerous cases the only notification which the Society has of a change of a member's address is a letter stating that THE JOURNAL, or some other communication, either was delayed in delivery or was not received at all. It is, of course, impossible for the office to have a correct list of addresses unless the members send in such changes promptly. All members who are receiving mail addressed improperly are urged to send their correct address to the office.

A list of the members for which the Society has no correct address is given below. Communications sent to the last known business connection or mail address as it appears on the records have been returned to the New York office. Any one who can supply information regarding the present location of these members or offer any suggestions as to where their correct addresses can be obtained will confer a favor upon the Society by communicating with the Secretary at the New York office. It is only by the cooperation of the entire membership that a correct mailing list can be maintained and the members receive THE JOURNAL and other communications promptly.

Anderson, A. H.
Bradley, Edwin Paul
Green, L. P.
Hagelthorne, G.
Johnson, A.
McNulty, G. Harold
Nordeman, P.
Tucker, Gordon E.
Wilson, Cyril

Discussion of Papers at the Farm Power Meeting

THE discussion of the papers presented at the Farm Power Meeting of the Society, held at Columbus, Ohio, Feb. 10, included both written contributions submitted by members who were unable to be present and the remarks made at the meeting. In every case an effort has been made to have the authors of the papers reply to the discussion, both oral and written, and these comments, where received in time for publication, are included in the discussions. A brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, for the convenience of members who desire to refer to the complete text as originally printed and the illustrations that appeared in connection therewith.

THE CARBURETION OF ALCOHOL

BY A. W. SCARRATT

THE author describes the development of an alcohol-burning tractor engine, after having stated a few of the fundamental requirements for burning alcohol economically and the results that can be attained by following them. The first trials were with 127-lb. gage compression at a normal operating speed. The problems attacked were those of what amount of heat applied to the mixture is desirable and its general effect on economy, output and operation; power output; general operation of the engine; and fuel consumption. The experimental work was done on a 4¼ x 6-in. four-cylinder 16-valve engine; this is described in detail and the results are presented in chart form. The conditions necessary for the proper use of alcohol as a fuel are discussed. [Printed in the April, 1921, issue of THE JOURNAL.]

THE DISCUSSION

PROF. C. A. NORMAN:—There have been a considerable number of investigations regarding the possibility of using alcohol as a fuel for carbureting engines, and, with certain modifications of the engine, alcohol is a good fuel, giving a high thermal efficiency. The difficulty in America comes in supplying alcohol in quantities sufficient to play any important part in the automotive field and at prices low enough to make it competitive with other kinds of fuel.

In Germany large quantities of fuel alcohol are produced, mainly from potatoes. In this country we could do the same thing. We could also readily manufacture alcohol from corn. The yield might be about 2.70 gal. of alcohol per bu. of corn and about 0.75 gal. per bu. of potatoes. This would mean that about 5 to 10 per cent of the total farming acreage in this country, if cultivated with only moderate skill, would be enough to supply almost the whole automotive demand for fuel. It would not mean a revolution in agriculture. On the other hand, to produce alcohol salable at something like 50 cents per gal. or less, potatoes would have to sell for 15 cents per bu. and corn for about 50 cents. Such prices would not be very attractive to the farmer.

The possibility of manufacturing alcohol from farm waste products such as straw and cornstalks has long been thought of and some experiments have been conducted by the United States Government to determine what can be done in this line. So far it seems that the difficulties of commercial production of alcohol from these sources are very great, and perhaps the difficulties of collection and organization of the industry are as great as those of chemical conversion.

In Switzerland an extremely interesting process for manufacturing alcohol from coal by way of calcium carbide appears to have reached the commercial stage, the cost being surprisingly low. However, to supply the automotive fuel demand of this Country by this process, about 16,000,000 hp. would have to be applied continuously through the year. Our all-year waterpower amounts to only about 25,000,000 hp.

It seems that there is in America an almost unlimited source of fuel similar to the present-day petroleum fuel in the form of shale oil. In Colorado there is an estimated supply of 20,000,000,000 bbl. of shale oil in shale of fairly high yield. In southwestern Indiana there is a reserve of 100,000,000,000 bbl. in shale yielding about 10 gal. of oil per ton; even with such low yield it appears possible to produce automotive fuel at prices much below those at which alcohol could be produced. Judging from circulars of the Colorado School of Mines, some companies are now producing in the West shale oil on a commercial basis; some estimated figures given by apparently reputable and financially strong organizations, in California for instance, show a cost of production per barrel of shale oil lower than the present selling price of crude petroleum.

Nevertheless, alcohol as a fuel is of great interest in the foreign field, which at the present time is attracting more and more attention from American business, and for this reason as well as on account of the more or less special cases where alcohol can be used as a fuel of secondary importance in this Country, experiments and preparations such as those undertaken by Mr. Scarratt are of value. In this connection it may be of interest to recall the rather striking fact that the best all-round fuel mixture developed in Germany during the war consisted of benzol, alcohol and kerosene in equal proportions.

F. C. ZIESENHEIM:—Will Professor Norman give us some idea of the composition of shale oil?

PROFESSOR NORMAN:—The composition of shale oil in Colorado, as determined by Mr. Winchester of the Bureau of Mines, is somewhat similar to that of Pennsylvania crude oil. It seems desirable in view of the present fuel situation to develop an automotive engine capable of burning any kind of liquid fuel, non-volatile as well as volatile. If shale oil generally were of a composition

similar to that stated by Mr. Winchester, it would furnish a great quantity of fuel capable of being consumed in carbureting engines.

D. R. HARPER:—The process of producing alcohol from farm waste or any similar source is inefficient in so many ways that it is probable that a zero cost of raw material would not balance the losses inherent in the process. The primary process, namely, fermentation, is of a biological and not an engineering nature. We have virtually no control over its efficiency, and unfortunately it is a relatively ineffective process. Until the biologist knows much more about fermentation the engineer or alcohol technologist must remain content to take what nature gives him, which happens to be a rather weak liquor. Inasmuch as we start with a weak liquor, we must have distillation. The heat units necessarily consumed in this stage are so vastly many times more than we can expect to get back from alcohol as a fuel that there is an incentive to apply the distillation power source in some more efficient channel. Deep-seated natural reasons underlie the difficulties met by the alcohol production engineer; for example, inability to keep his plant busy long enough during the year to pay the interest charges. We cannot prod him to such great efficiency while the plant does work as to overcome the handicap of intermittent operation. The waterpower production method mentioned by Professor Norman is of interest as eliminating the biological factor and providing a process that is apparently more nearly under control.

D. L. ARNOLD:—We may not need to produce alcohol for engine fuel within our own lifetime but our children may have to produce it. When it is produced it will be a matter of by-products; alcohol alone will not be produced. The whole process must be taken into consideration in connection with the cost of producing alcohol.

An interesting method of getting power from straw and similar refuse products has been demonstrated in northern Canada. The trouble with the process is that no one has found a way to condense the gas that comes out of the straw. The heat value is there and some day somebody will find a way to do that. At present lampblack is obtained at the rate of about 400 to 600 lb. per ton. The price is 10 to 15 cents per lb. On a by-product basis the manufacture should not be too expensive.

F. F. CHANDLER:—With reference to Mr. Scarratt's experiments on alcohol, what did he find regarding so-called preignition?

A. W. SCARRATT:—There is absolutely no preignition.

CHAIRMAN E. A. JOHNSTON:—A prominent farmer near Chicago, who cultivates several thousand acres, suggested he would like to produce alcohol for power purposes from waste vegetable matter. I cooperated with him to some extent in looking up apparatus and the cost of production, but when we learned the details of the Government requirements covering the production of alcohol, we decided to give the matter up.

MR. SCARRATT:—I am optimistic regarding the fuel question. We have made very little use relatively of our knowledge of chemistry. We have ahead of us an enormous field in which we can be sure that the chemists will take a very active part within the near future. Within 5 years we will have revelations regarding fuel that will set aside all the anxiety we have at present.

CHAIRMAN JOHNSTON:—Under the present state of development the automotive engine, properly designed and constructed, will consume about 0.63 or 0.65 lb. of kerosene per hp-hr. and about 0.52 or 0.54 lb. of gasoline under favorable conditions.

Alcohol is fine fuel to use; one need not worry about the carbonization. It burns well; of course, it has some disadvantages, but this is true of every fuel we deal with.

NEBRASKA TRACTOR TESTS

BY OSCAR W. SJOGREN

BEFORE taking up the results of the tests, the author states briefly the provisions of the Nebraska tractor law, the kind of tests conducted and the equipment used.

Applications covering 103 different tractors were received during the season; of the 68 that appeared for test, 39 went through without making any changes and 29 made changes. The results of the tests are described and illustrated by charts.

The fuel consumption was studied from the three different angles of volumetric displacement, engine speed and the diameter of the cylinders, the tractors being classified accordingly and the results presented in charts which are analyzed. The weaknesses of the tractor as shown by the tests are commented upon at some length with a view to improvement of the product. [Printed in the May, 1921, issue of THE JOURNAL]

THE DISCUSSION

G. R. PENNINGTON:—The tractive force or total force exerted against the ground which a tractor can develop is a constant. The maximum available drawbar pull is equal to this tractive force less the force required to move the tractor itself and is therefore a variable depending upon soil conditions. In certain cases we are more interested in knowing the tractive force or tractive horsepower than the drawbar pull or drawbar horsepower available. A usual way to determine the maximum tractive horsepower is to measure the drawbar horsepower and add to that the power necessary to pull the tractor itself at the given speed. Have you tried that method?

PROF. O. W. SJOGREN:—No. We tried to test the tractors in the same way the farmer would use them.

A MEMBER:—The test sheet shows that the prevailing fuel was kerosene. It has been brought to the attention of many that there is a growing aversion to the use of kerosene as it is handled in the present carbureter system. What is Professor Sjogren's opinion as to the economic status of low-grade fuels?

PROFESSOR SJOGREN:—I do not know that I am in a position to give a definite answer to the question. The amount of gasoline used was practically the same as the amount of kerosene. We get practically as much horsepower from a gallon of kerosene as from a gallon of gasoline, provided the tractor is designed for kerosene.

MR. PENNINGTON:—Does the increase in crankcase oil dilution, which we get with lower-priced fuels, make up for the difference in price between kerosene and gasoline?

PROFESSOR SJOGREN:—I believe it does not.

PROF. W. T. MAGRUDER:—I would like to know why due allowance was not made for the power lost in transmission between the belt pulley and the dynamometer.

PROFESSOR SJOGREN:—Because we want to know what amount of power the farmer can take off; also because there was no definite rule for determining the loss without making a calibration of each machine. We discussed that for a long time before we arrived at our conclusion; we decided that, to be fair to everyone, the best method was to measure the power at the brake end.

PROFESSOR MAGRUDER:—Tests show that it makes a considerable difference how the power is taken off. For accurate results the dynamometer should be tested and the pull of the tractor on it standardized; otherwise results differing by 1 to 2 hp. will be obtained, which is a large percentage of the gross power.

CHAIRMAN E. A. JOHNSTON:—Most engineers appreciate the fact that belt power losses very considerably under different conditions of transmission. Unfortunately many manufacturers have not made sufficient allowance for belt clearance. The farmer is interested in the power delivered to the belt of the driven machine, as Professor Sjogren states.

D. L. ARNOLD:—To compare the performance of all tractors the maximum drawbar pull and the maximum belt horsepower, were reduced to a piston-displacement basis. On that basis I found that only two of the tractors tested fell below delivering 50 per cent of their belt power to the drawbar, while the tractors of highest efficiency came close to 82 per cent. Of course, that takes into consideration the friction of the transmission and driving mechanism to pull the tractor under load.

PROFESSOR SJOGREN:—That is probably due more to the condition of the track. We used a cinder track because we felt it could be maintained in a more uniform condition throughout the season than a dirt track, and because it was more like a stubble field.

H. W. RILEY:—Were the lugs uniform in every case?

PROFESSOR SJOGREN:—We made no specific point of investigating the equipment. We allowed the manufacturers to use what lugs they thought worked best; they investigated that and were in a better position than we were to make the proper choice.

MR. PENNINGTON:—In view of Mr. Arnold's statement, I wish to explain the reason for my question. If two tractors, which on the cinder track develop the same drawbar horsepower, were taken out in a soft field, one tractor might then deliver much more drawbar horsepower than the other, for the reason that less horsepower might be consumed in moving this tractor itself. The amount which a tractor sinks into the ground largely governs this factor. A comparison on a cinder track is not therefore sufficient for all purposes. We are interested also in knowing the power it takes to move the tractor over any given soil. I would like to ask whether Professor Sjogren has made any measurements of that kind.

PROFESSOR SJOGREN:—No.

J. A. SECOR:—I understand that the different kerosenes and gasolines used in the tractors varied considerably. Was any average quality determined for the kerosene and the gasoline as a whole that was used as fuel for all the tractors?

PROFESSOR SJOGREN:—The variation was very slight. We struck no average.

MR. SECOR:—The average would be about 6.75 lb. per gal. for ordinary kerosene, and 6.20 lb. for engine gasoline. These weights correspond with 43.2 deg. Baumé for the kerosene, and 58 deg. Baumé for the gasoline. Lighter or heavier kerosenes and gasolines should be within 1 per cent of these averages.

A. R. SANDT:—Did Mr. Sjogren determine whether the breakages were due to poor material or to faulty engineering?

PROFESSOR SJOGREN: — I think our report specifies whether there was poor material or poor engineering, and that it runs about half-and-half. Where the report said that considerable wear was noticed, I concluded what the main difficulty was. In one case where the flywheel flew to pieces, we concluded that we could not determine whether that was due to faulty engineering or faulty material. That happened when the operators were not present. The engine was started and seemed to accelerate very rapidly. It appeared that somebody had used a wrench on it. That merely goes to show that on a test one must be very cautious and watch every detail to get accurate results. When we made mistakes in our testing work, we tried to remedy them as soon as we noticed them. We did not get all the information we should have secured because of the pressure of the work. You can imagine what it means to have 103 tractors to test during a season, each one of which must be run from 20 to 50 hr.

A. W. SCARRATT:—Professor Sjogren mentioned the difficulty experienced with spark-plugs generally. I do not wish to defend the spark-plug manufacturers, but if the implement manufacturers will pay a little more attention to the design of their engines, with reference particularly to carburetion, lubrication and cooling, they will not have so much trouble with the spark-plugs. We have tested nearly every reputable make of spark-plug that is not of freakish design and of all of them there are about three that we can say do not stand up satisfactorily. This may not be the case with all engines. More attention should be paid to carburetion to make it thorough and complete; to the proper distribution of the lubricant, especially to prevent excessive lubrication; and to the timing. This will help to clear up much of the spark-plug trouble.

O. B. ZIMMERMAN:—We should extend a vote of thanks to the Board of the Tractor Test Committee of Nebraska for the extreme fairness and frankness with which they carried on this whole series of tests. They have been so generous in their courtesy that I am sure all of us will have gained much information from this analysis.

The questions have indicated that there are many things we would like to have incorporated in the analysis and undoubtedly they can be incorporated in the series of tests of next year. We would like to know what the relation actually is between the maximum drawbar pull of a tractor and its weight. That is, of course, obscured by lugs, wheel diameters and wheel widths. We should give much attention to lug and wheel data from an engineering standpoint. These factors constitute perhaps the weakest point in our general understanding of design considerations today. In traveling over the ground, we must look upon the whole tractor design from two standpoints, the effect of the weight and the effect of the lugs.

The plow itself should be designed to give a maximum disturbance of soil for a minimum expenditure of energy. The tractor itself, or the part which takes hold of the ground, should be designed with a contrary view, that of getting the minimum disturbance of soil and enabling us to transmit the greatest amount of power. In many of the tests which we are endeavoring to analyze, for instance, the relation of speed to draft, the actual data that interest us are covered up to a certain extent by the fact that altogether too often the soil is disturbed before the plow takes hold of it. That is particularly true when

we use the higher speeds. Inasmuch as all these data are taken at the drawbar, we must watch with care and not upset the analysis by believing that all of this work is done by the plow, when a good share is often done by a disturbance of the lugs, perhaps by a pressure which the engine carries to it and by narrow wheels. So, I think we should look into this matter of the design of wheels and lugs very carefully. We should also pay great attention to the transmission, the engine shaft and the rear axle.

In studying these Nebraska tests, I hope the analysis will include consideration of the enormous amount of power that is lost between the engine shaft and the drawbar. It seems almost foolish to lower the fuel consumption on the brake test and then lose in the transmission seven or eight times as much as seems necessary. I think that will show that we have given excessive attention to the engines. It will be found that many engines give excellent fuel consumption in relation to the power delivered at the engine shaft, but are excelled by many other engines when the power is measured at the drawbar. I hope we will soon analyze the power losses in the bearings and the gearing and those due to wheel design and the like.

PROFESSOR MAGRUDER:—In comparing with the drawbar horsepower the horsepower delivered at rated load for 2 hr., I find that the drawbar horsepower per gallon varies from 33 to 82 per cent of the actual horsepower at the pulley. I suggest that the Research Committee investigate why we lose this large amount of power in transmission.

MR. SANDT:—Did Professor Sjogren notice any particular difference between the various types of final drive?

PROFESSOR SJOGREN:—I will ask you to take the tabulated reports and draw your own conclusions.

A MEMBER:—I suggest that, if possible, during the next series of tests, standardized belts that are suitable for the pulley widths be used, and that the slippage on different diameters of pulley be obtained.

PROFESSOR SJOGREN:—The belt slippage was given for each test in the official reports. We shall be glad to receive suggestions from the Society as to items that should be included in our next report. We expect the coming season to be fully as strenuous as the last one was. We have had 20 requests for tests and that is about the same number we had last year at this time.

H. W. SIMPSON:—Why are some of the tractors ratings omitted?

PROFESSOR SJOGREN:—Because the firms make no rating. The ratings shown on the chart are the manufacturers' ratings.

E. R. NASH:—Why are some of the lug data left out?

PROFESSOR SJOGREN:—Where lug data are not given, the tractors were of the crawler type, no lugs being used.

R. I. SCHONITZER:—Did the test include a record of the results obtained with different types of bearing, such as plain, ball and roller, as used in engines and transmissions of the various tractors tested. Were the results obtained with different types of lubrication system included?

PROFESSOR SJOGREN:—No, but we will be glad to include additional interesting features in future tests if the members of the Society will make suggestions.

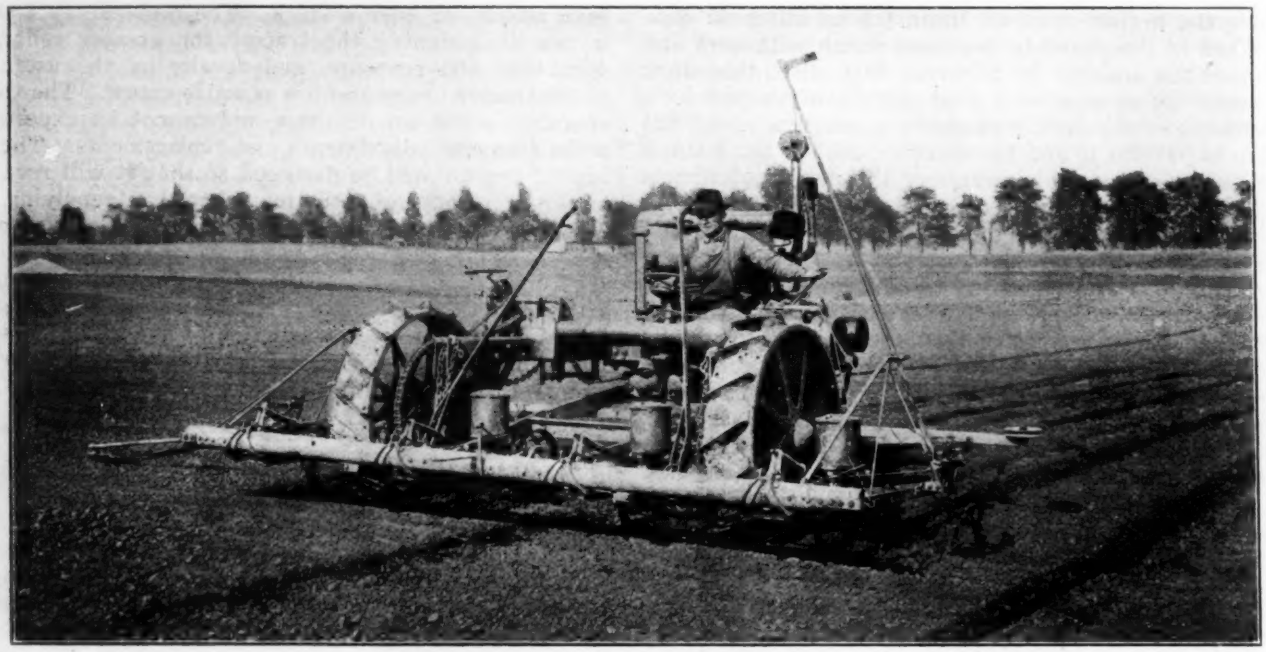
CHAIRMAN JOHNSTON:—The tractor industry will succeed in direct proportion to our ability to make tractor operation profitable to the tractor user. This should control the trend of tractor design. In the early days it was a question whether tractors should have two, three or four wheels, or have a track. The problem, as I see it, is one of designing the tractor for greater reliability, durability and economy, and developing the usefulness of the tractor to the greatest possible extent. The tractor operator is not an engineer and cannot be expected to make frequent adjustments and replacements. The successful tractor will be designed so that it will require a minimum amount of attention other than supplying fuel, lubricant and water once or twice daily. Gear, sprocket, shaft bearing and other pressures and stresses will be kept low enough to insure durability and eliminate breakage. Obviously, only material of the highest grade should enter into the construction of the modern tractor. The economic use of fuel and lubricants and convenience of operation are important factors.

THE FUTURE TRACTOR

The future tractor should be provided with a take-off to transmit power to binders and other implements. On most farms, diversified farming is carried on to such an extent that power must be applied to many implements that cannot be operated profitably with tractors designed for heavy drawbar and belt work only. The farmer's problem is one of production and the cost of production. As the cost of labor averages 40 to 50 per cent of the total cost of production, it is clear that the production per man must be increased to decrease the cost of production. This is an engineering problem and can be solved by the proper application of automotive power to agricultural equipment. I will not attempt to say how it can be best accomplished, but will present some recent developments that have a bearing on the solution of the very important problem of the application of automotive power to agricultural equipment.

This power machine is designed with two drivers, and can be operated in either direction. The plows can be attached and detached conveniently and quickly. The operator's seat is rather high, but he is up out of the dust. That is one of the advantages. One of the drivewheels operates in the furrow, which is beneficial under

A POWER-DRAWN TWO-PLOW OUTFIT



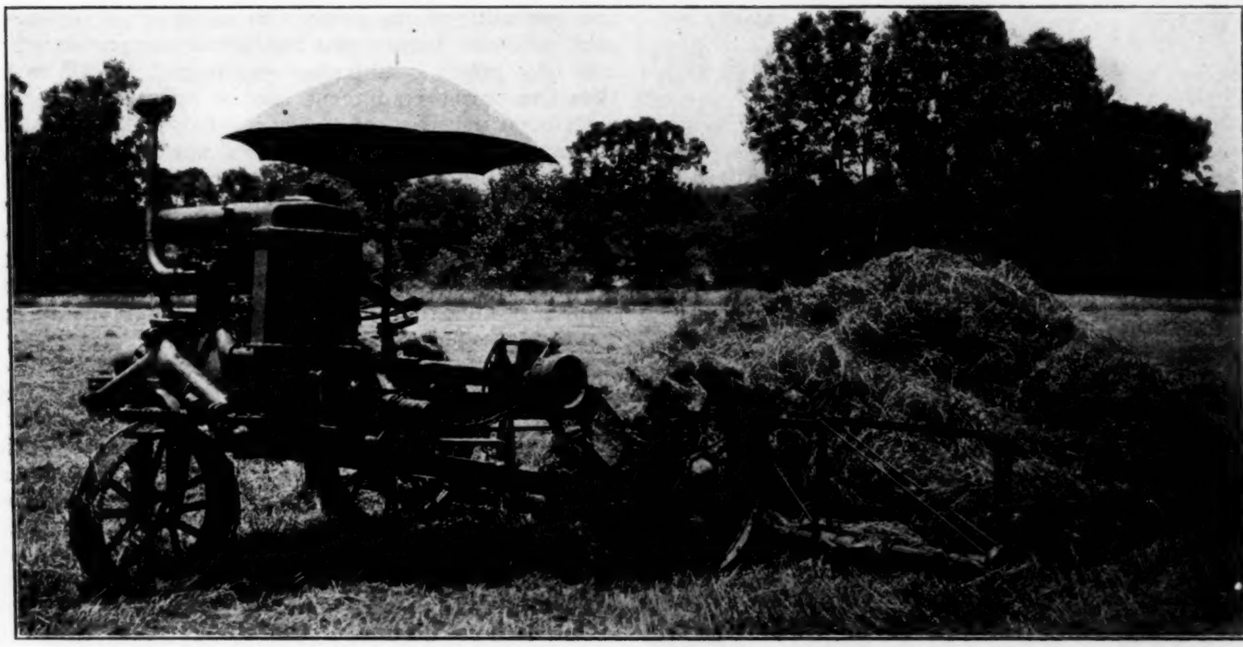
A Four-Row Corn Planter

some conditions, in fact, under most conditions. The same tractor operates a four-row corn-planter, planting about 2½ times as much acreage per man as the ordinary two-row horse-drawn planter. The four-row planter weighs and costs slightly more than the two-row planter and can be attached and detached quickly and conveniently. It is designed to turn short. The power-operated cultivator can be attached and detached quickly and guided quickly with very slight effort by the operator. This cultivator costs about 75 per cent as much as the horse-drawn cultivator and cultivates two rows at a time.

A power-operated mower has a 14-ft. cut, twice the width of cut of the horse-drawn mower. The mower in this case costs just about the same as the 6 or 7-ft.-cut horse-drawn mower. One operator can mow hay at the rate of 4 acres per hr., which is about three to four times the capacity per man with a team. The bars are raised quickly and automatically. Besides, there is a hay-rack with a capacity of 12 to 14 ft., increasing the capacity per man 300 to 400 per cent. All of these implements can be attached conveniently and quickly without the use of any tools or removing any bolts.

A wide power-driven sweep-rake and grain-shock gatherer can be folded up for passage through fence gates, and unfolded for operation afterward. It has a large capacity as a sweep-rake, and the same implement when

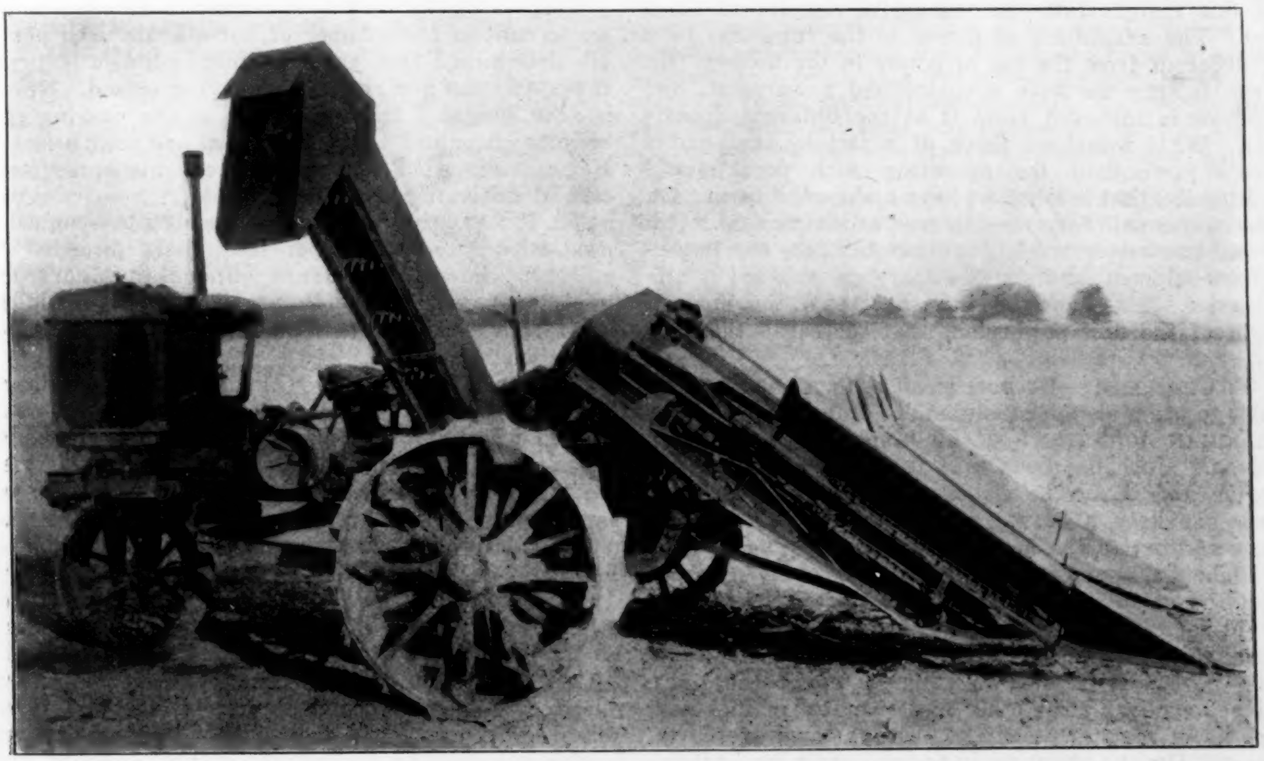
The Two-Bar Mowing Machine



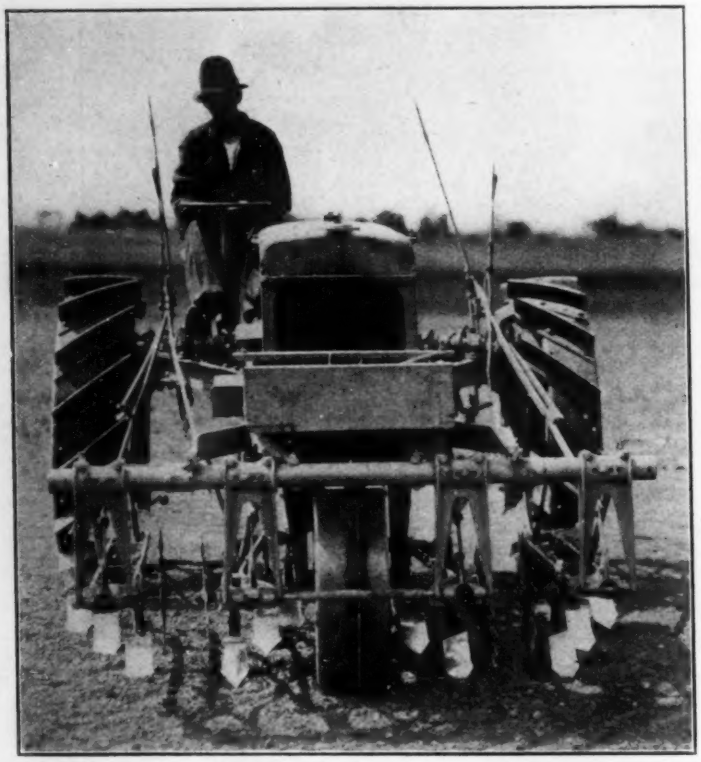
THE SWEEP RAKE AND SHOCK GATHERER

gathering shocks has a capacity of from 8 to 12 grain-shocks. It gathers the shocks without shelling the grain as badly as when pitched by hand. It has a capacity sufficient to enable one operator to keep a small separator fully supplied. With it a man can do the same work that ordinarily three teams and six men accomplish. There is much lifting to be done on all farms. A power-operated derrick has been adapted to this same machine to handle hay or do other lifting such as loading corn stalks out of the field and onto the wagon. It is often desirable to remove the corn-shocks to enable the farmer to plow. Corn-shocks are very difficult to handle by hand.

The 10-ft. binder and harvester weighs and costs approximately 60 per cent as much as the conventional horse-drawn machine; it can be equipped with an automatic shocker. The same machine handles a grain-header that has an 18-ft. cut. The header weighs and costs slightly more than half as much as the regular horse-drawn implement. It has the advantage of opening up a field without tracking down the grain. This machine is an adaptation of a horse-drawn corn-picker, which weighs less than 2000 lb. as designed for use in connection with the power machine. Its operation is very much improved by maintaining a uniform motion. There is also a



A TRACTOR-OPERATED TWO-ROW CORN PICKER



THE TWO-ROW CULTIVATOR

tractor-operated two-row snapper, which picks the ears from the stalks without husking them.

With all these machines the power is transmitted directly from the engine to the machine, which is a great advantage in operation. Regardless of the movement of the machine forward, it operates at uniform speed, which results in a high grade of work.

PRESIDENT DAVID BEECROFT:—This session has given us a fine insight into the wonderful chapter of farm power. The adaptation of power to the farm has been very different from the use of power in the factory. In a large factory we have a centralized powerplant, and the power is conveyed from it to the different departments. What would we think of a factory that had a separate powerplant for operating each department? But, literally, that is what we have had on the farm. On a relatively small farm in Minnesota one man had two tractors, two motor trucks, two automobiles, one house-lighting equipment and six stationary gas engines of different size. Mr. Johnston has illustrated the modern thought of the unit powerplant that serves all the purposes.

F. F. CHANDLER:—Or how small a farm would it be possible to use a combined equipment economically?

CHAIRMAN JOHNSTON:—It all hinges on the cost of operation. Much has been said about the cost of horse operation and it can be elaborated on to an enormous degree. To keep a horse requires the product of five acres, according to the best information available. The feed is about 60 per cent of the cost of keeping a horse, so that the value of the product required to supply the other 40 per cent means that a total of about 8 acres is required to keep a horse. It is possible, as I see it, to develop power-driven farm equipment along the lines mentioned or along some other line so that machines will replace all of the horses on the average farm of 100 to 150 acres. Usually about seven to ten horses are kept on a 150-acre farm. If there were only six or seven horses and the value of the product of eight acres is taken for each of those horses and the result compared with the cost of a power combination equipment, it will be found that the power equipment can be operated at approximately 60 per cent of the cost of operating by horses. Ultimately, of course, the cost of operation and of production will determine the answer.

MR. CHANDLER:—That possibly answers the question as far as it can be answered at present. What I had in mind is how small a farm it is possible to operate with a tractor and combined power-driven implements; for instance, if all of the combined cost due to horse equipment were applied to power-operated implements, how would that combined value of the horse equipment compare with the combined cost of the machinery that is desired to replace it?

CHAIRMAN JOHNSTON:—One of the great advantages to be obtained by some such development is the reduction in the weight and cost of implements. The power-driven implements will cost from 40 to 75 per cent less than horse-drawn implements of equal capacity. Perhaps I can answer the question by saying that the tractor for heavy belt and drawbar work is being developed rapidly. It has been developed to a point where there is no question as to its usefulness or as to its being a profitable investment for a farmer who tills 75 acres or more. Obviously, to reach the small farms, some such development as I have described must be accomplished because, if the small farmer carrying on diversified farming can use his tractor only for drawbar and belt work, he can make profitable use of the tractor for only approximately six to eight weeks in the entire year and it will be necessary for him to keep approximately the same number of horses as before to handle his row crops, which could not be handled to advantage with a tractor developed for drawbar and belt work only. Summing the matter up, as nearly as I am able to determine, a properly developed combination outfit can be used profitably on farms of 50 acres or even less.

FRED C. ZIESENHEIM:—A farmer in Pennsylvania kept an account of the number of horse-hours used per year. He determined that the maximum number occurred in the cultivation and not in the plowing season. Nevertheless he bought a tractor for use in the plowing season, because he gained time; he gained one month last year. He was compelled, however, to keep his horses to take care of cultivation and emergencies.

MR. PENNINGTON:—Why are implements designed to be used with tractors cheaper than those intended to be pulled by horses? It seems offhand that horse-drawn implements would be cheaper since they are pulled at lower speed and can therefore be made of lighter construction.

CHAIRMAN JOHNSTON:—On all machines designed to be pulled by horses, the power is transmitted from a ground wheel into the machine through a transmission mechanism. The weight and cost of the carrying wheels, the transmission mechanism and the construction necessary to carry that mechanism are eliminated in the implement designed to be operated by power along the lines I have described.

C. A. ATHERTON:—What are the possibilities of operating tractors at night, and the probability of equipping all tractors with electric lights as standard parts?

CHAIRMAN JOHNSTON:—That is a very interesting question. When we commenced to sell tractors 10 or 15 years ago, there was a demand for lighting equipment in the Dakotas and the prairie country. Night tractor operation was carried on to a considerable extent. In a

general way the operation of tractors at night results in just the same expensive unsatisfactory operation as night work in a factory, excessive breakage and higher cost of operation per unit of work. Furthermore, there are many farming operations which cannot be done to advantage at night on account of dew and other conditions. While there is some demand for lighting equipment to operate tractors at night, it has not been sufficient to justify supplying it as standard equipment.

MR. ATHERTON:—I am not a farmer or an agricultural engineer. I am looking at the subject from an illumination point of view. It seems to me that the farmer has less choice as to when he shall work than has an operator in any of the other industries. He is more dependent upon the seasons and must work when conditions are right. It is necessary frequently for him to put in 24 hr. of work at the right time. In a late spring the farmer might have to crowd all his plowing into one-half the time that he would ordinarily devote to it.

CHAIRMAN JOHNSTON:—Your thoughts along that line are correct but in practice they must be modified. The small farmer may have one man to help him or a man and a boy or two boys. He cannot operate 24 hr. without additional help. It has been difficult to get help of any kind. On the larger farms the equipment is generally adequate to perform the farm operations at the most desirable time. There is very little demand for tractor lighting equipment at this time.

MR. SANDT:—Is there any demand for starting apparatus?

CHAIRMAN JOHNSTON:—There is always a demand for starting apparatus or any convenience on a tractor, the same as for any other device or machine. The conventional starting device operated electrically and requiring a storage battery has not been developed to a point where it can be used generally on tractors; at least that is the attitude of most tractor designers. Starting equipment is standard on some tractors, and seems to be very satisfactory; but, in a general way, I believe that tractor development is not at a stage where it should be complicated with electric starting apparatus.

MR. NASH:—On the large farms in California and along the Pacific coast it is the practice to use the tractors at night to a great extent, and electric lighting is largely used there. A few tractors are equipped with gas light, but the most satisfactory equipment appears to be a generator of approximately constant voltage driven as seems best and operating without the use of a storage battery. One of the manufacturers brought out a gear drive for one of these generators which no doubt will prove much more satisfactory. Our most successful owners, during their plowing and seeding season or in doing discing or anything of that kind, operate 22 hr. daily for six days. On the seventh day they lay up and go over the rigs. They will not stop during the week except for an emergency.

COMING AERONAUTICAL DEVELOPMENTS

IN spite of the depressing conditions under which the aeronautical industry is laboring the technical development of the flying machine is not by any means being neglected. On the contrary, experimental and research work of a bold and ambitious nature is being actively prosecuted in many quarters. Ideas are changing and advancing rapidly, almost if not actually as rapidly as they did in the war period. During hostilities the progress made was great outwardly, but, in point of fact, it was very largely indeed composed of a refinement of detail, a growth in the absolute size of machines, and a development of the country's capacity to build them, their engines and accessories. Of genuine technical evolution, the war period showed much less than is ordinarily supposed. The airplanes at the end of it, with one or two exceptions, were substantially the machines of 1914 with increased performance and added powers. None of the belligerents could afford to spend much time developing radically new and untried ideas. The progress effected was truly remarkable, but it was practically all made within the lines of the earliest machines to take the field. Today, with the leisure enforced by the dullness of constructional activity, the country's aeronautical designers and research workers are exploring fields that, although visible during the war, were by force of circumstances all but forbidden to them. The evolutionary tendencies in play at the present moment are powerful and widespread, and if the industry can be granted survival for a space, they will almost certainly result in the near future in practical developments, besides which the progress made during the war will assume considerably less importance than we have been accustomed to accord to it in the past.

Let aerial transport, whether by flying machines or dirigible airships, attain an equal degree of safety, economy and trustworthiness to that of the railroad and the steamship, and it will be impossible for the public to avoid accepting it as a part of its daily life.—*The Engineer* (London).

DIESEL ENGINE SIZE

THE reciprocating steam engines of the steamship *Olympic* have cylinders of 4000 hp. each, so that a single four-cylinder engine develops 16,000 hp. A Diesel engine developing only 250 hp. per cylinder would, of course, require 64 cylinders to give the same power. The enormous multiplicity of parts to be looked after and kept in adjustment, even if this were individually easy, would be sufficient to prevent such use, while, in fact, the Diesel engine requires unusual care and attention to keep it in good order.

The question naturally arises, "Why is it that the Diesel engine cannot be built in large sizes?" Like all other internal-combustion engines, the Diesel engine requires that the cylinders be water-jacketed to keep the barrel sufficiently cool to permit the proper working of the pistons. The pressures carried are high, from 700 to 1000 lb. per sq. in. requiring a thick cylinder even for a power of 250 to 300 hp. The fact is this thickness is evidently about the maximum that will permit the interior cylinder wall to be kept of a sufficiently low temperature for satisfactory working. It happens that cast iron is by far the best material that has ever been found for the cylinders of quick-moving reciprocating engines. If a material having all the fine wearing qualities of cast iron with several times its thermal conductivity could be found, we might expect Diesel engine cylinders of greater power; but until that comes, or there is some other radical invention, the nature of which is not now evident, the Diesel engine seems limited to small powers.—W. M. McFarland in *American Machinist*.

PROFESSIONAL ENGINEERING EDUCATION

FOR some reason members of the principal engineering societies and associations of this country are deeply dissatisfied with their professional status, as indicated by the failure of the public, as they claim, to give the members of the profession proper consideration in their professional work. There have been many meetings, joint and individual, of these societies and associations, for the purpose of discussing this failure to receive sufficient professional recognition from the community at large. New organizations have been created recently to secure better professional recognition.

A great majority of our engineering schools are called "colleges of engineering." Obviously the mere name of an educational institution is of subordinate consequence. In the present instance, however, calling a professional school an "engineering college" makes a course of study that ought to be thoroughly professional in character merely a scientific college course, and that is the fatal defect of a great majority of the engineering schools. They are neither professional schools nor are they in reality colleges. They are a kind of hybrid that produces neither the broadly educated college man nor the educationally trained professional man. Some of them have served well a transition purpose, but the type is far from that of a professional school.

More than 70 years ago the oldest engineering school in America, Rensselaer Polytechnic Institute, reorganized its professional course of study with a vision as to the future both wise and remarkable. It sought to establish a professional school of engineering and applied sciences by formulating a course of wholly professional study of three years' duration to which college graduates were invited to come for their professional engineering training. It was fully 50 years in advance of the time when such an effort could possibly succeed. The experiences of the first year of this course of professional study showed that it then had no prospect whatever of success. To remedy the difficulty a preparatory year of study was formulated so that non-college graduates could thus prepare to begin the three-year course of professional educational work, making four years in all. This was the origin of the prevailing four-year course of engineering study which has become general throughout the United States. It would appear that the idea of basing professional engineering educational training on a broad general schedule of study such as that afforded by the usual college course has somehow dropped out of all consideration whatever, except in a few rare cases. There is distinctly a feeling that something needful is not included in the present engineering courses, even in the mind of those who administer and defend them, and their apprehension is too well founded. There is something of the utmost importance lacking. Both students and instructors of those institutions yield, although unconsciously, incontrovertible evidence of that fact.

Comparison With Law and Medicine

I am well aware that many engineering instructors and practicing engineers who are interested in engineering education argue that the engineering profession is in some way so different from the learned professions of the law and medicine that the general type of educational training which they have adopted for entrance into those professions is not suitable for the educational training of young engineers. They now require in their best professional schools a broad general education acquired in the college on which to base the professional educational training. Anyone who is observant enough will find that a large proportion, and probably the majority, of those two professions who have reached the beginning of middle life are men, broadly speaking, not only of technical ability and excellence but also possessing what may be termed, in the broad sense cultivation. They can take their places with credit to themselves in any place in the community where they may be called. They possess individuality and those qualities of mind and character that demand and receive public recognition both in and out of their professions. It is not necessary to enlarge upon the lack of such acknowledged position in the community on the part of engineers, for they themselves have set it forth within the past few years in clear and unmistakable terms. All curative efforts made through engineering organizations, are bound to fail in large part as they have failed up to the present time, unless one fundamental condition is first fulfilled and that is, the engineer must have a full professional education as a basis for his professional career before he can properly demand or be accorded by the public, full professional standing. Indeed, if it were feasible to give every engineer in the country a suitable professional educational training the profession would in a short time attain to the high position that it covets and be accorded by the public, full professional standing. Indeed, striving to attain, without any other aid whatever, just as the professions of law and medicine have done.

The high position and the great advantages reached by any profession are actually due to the acknowledged character and attainments of a majority whose capacity and character make them marked individuals and whose prestige gives standing to the entire profession.

Introducing Six-Year Course

The four-year course of engineering study has served a purpose and served it well, but I believe it can be stated without being effectively controverted that by far the best results have been reached where the course of engineering study has been based upon the broad course of general educational training given by colleges. I know that the usual standard objection will be made that there are few young men in the community who have sufficient time and means to take seven or eight years for such a course of study. In the first place it can be flatly stated that young candidates for law and medicine find it feasible to devote sufficient time for the desired purpose and I know of no reason why young candidates for the engineering profession cannot do the same thing if they have sufficient virility, resolution and, I hesitate to say, intelligence. In the second place, I can state from personal knowledge and experience that seven or eight years is not required. Six years is ample, three years in the college and three years in the engineering school. If our secondary schools were administered a little more intelligently it would be not only perfectly feasible but easy, as it has been in many cases, to give a young man this six-year engineering course of study and graduate him ready to begin his active practice at 22 years of age, which is a less age than that at which many and perhaps a majority of young men graduate from the standard four-year engineering course.

In the case of the four-year course, the student not having had any prior general education at a college or elsewhere, it is probably wise to introduce as much English instruction during the first year as is practicable. A similar observation can properly be made in reference to one prominent modern language such as French or Spanish. Such general cultural subjects, however, should be limited to the first four years, and as soon as the required development permits the installation of a prior general education in a college of cultural or liberal arts work these subjects should be confined to that part of the educational training, leaving to the professional school the entire time set apart for technical work. Doubtless in some or even many localities it might take a considerable period of years to reach the full professional educational training consisting of a broad general education of not less than three years, leading to the professional school having a course not less than three years in length, but that is the end toward which all possible efforts should be directed. College courses taking no more than three years' time are now common.

It is no exaggeration to state that the hope of the future of the engineering profession in this country lies in the development of a proper professional engineering education which with exceedingly few exceptions has not yet been attained. The position of the legal and medical professions points the way with absolute clearness. The engineer must be made a

man of cultivation as well as of technical excellence. In order that he can become the most useful citizen possible he must combine with his rather narrowing technical excellence those qualities which give him character and standing an an individual qualified to win the esteem and respect of those about him for his executive capacity wherever he is found to possess the executive quality. In other words, he must be a man entitled to receive the confidence of the community in which he practises.—W. H. Burr, before the Society for the Promotion of Engineering Education.

SUBSTITUTES FOR ASH IN AUTOMOBILE BODIES

ASH has always been considered the most desirable wood for use in automobile bodies. It combines the properties of moderate weight, easy workability, high degree of toughness and comparative freedom from warping. On account of the high price of ash, however, other woods are gradually replacing it in all but the most expensive cars. Some of the advantages and disadvantages of the substitute woods as compared with forest-grown ash for automobile construction are presented in a description that has been prepared by the Forest Products Laboratory, Madison, Wis.

Hard maple is used for sills in many cars, and in some for the framework of the body and the floor and running-boards. Maple is fully as strong and stiff as white ash, but is not as shock-resistant. It is usually cheaper than ash and runs more uniform in strength. Maple warps very little, in this respect being superior to elm, but is more difficult to season without checking than ash or elm and does not hold screws so well. On account of the smooth, fine texture of maple, paint and enamel rub off it easily, especially on curved surfaces that receive considerable wear. Because of its smooth-wearing qualities and comparative freedom from slivers, maple is preferred to all other woods for the floors of delivery trucks and other vehicles carrying freight.

Elm is principally used for frames, seat backs and doors; very little, if any, is used for sills. White elm is preferred to rock elm, except for some of the bent parts, because it is more easily worked and is less subject to warping. For the same reasons lumber from old white elm trees, usually called gray elm, is preferred to that from younger trees. Old white elm is not so strong or tough as ash, on the average, but it varies less in strength.

Yellow birch is a close rival of maple. It is used for sills, framework and many minor parts and is said to hold the paint better than maple on exposed surfaces.

The true hickories are used almost exclusively for spokes and felloes. The pecan hickories, which are somewhat inferior as a class to the true hickories, might be used in body construction, although their hardness and tendency to twist would perhaps prove a serious fault.

Red gum is too weak and soft for the sills and other major parts of the body frame, but is used for floor-boards, seat risers and other minor parts. One of the principal disadvantages of gum is its tendency to warp with changes in the moisture content. Quarter-sawed gum gives less trouble from warping than plain-sawed gum.

In automobile construction no distinction is made, as a rule, between the different species of oak or even between the red oak and white oak groups. In truck bodies, oak is one of the leading woods, being used for sills, cross sills, frames, floors and stakes. Oak is rarely employed for the frame or sills of passenger-car bodies. Wormy oak is used for running-boards, floor-boards and seats, and some sound oak is used for instrument boards and battery boxes. Top bows are made almost exclusively of oak, second growth being preferred.

Longleaf, loblolly, shortleaf and some of the minor Southern pines have been found adaptable for running-boards, floor-boards, seat-boards and a number of small parts in the seats and frames.

Cottonwood is used for the dash of passenger cars and the boxes or bodies of trucks. Sycamore, beech, basswood, yellow poplar, cucumber, tupelo, gum, chestnut, Douglas fir and Western yellow pine have also entered into car body construction to a small extent.

The four physical properties most important in automobile construction are given for each of the different species in the accompanying table, the strength of forest-grown white ash being taken as 100. Actual strength values of these species are to be found in Department of Agriculture Bulletin No. 556, entitled Mechanical Properties of Woods Grown in the United States.

STRENGTH OF WOODS USED IN AUTOMOBILE CONSTRUCTION IN PER CENT OF THE STRENGTH OF FOREST GROWN WHITE ASH

Species	Strength as a Beam or Post	Stiffness	Shock Resisting Ability	Hardness
	Hardwoods			
Ash, white, forest grown	100.0	100.0	100.0	100.0
Ash, black	71.3	79.3	90.1	62.3
Ash, white, second growth	122.5	117.6	119.6	118.9
Basswood	59.1	80.6	40.5	29.6
Beech	93.5	96.9	96.0	90.0
Birch, yellow	104.8	116.8	120.6	80.9
Chestnut	66.0	71.9	53.4	49.2
Cottonwood	60.6	79.0	54.3	35.3
Cucumber	85.4	112.4	76.7	54.9
Elm, rock or cork	98.8	92.9	140.5	101.6
Elm, white	79.2	79.5	89.5	57.1
Gum, red	80.7	91.5	75.5	59.0
Gum, tupelo or cotton	81.4	82.5	63.5	77.3
Hickories, pecan	103.5	103.8	119.7	139.6
Hickories, true	126.6	120.2	173.9	150.4
Maple, red	90.0	101.2	78.7	75.4
Maple, silver	66.9	68.5	71.7	64.3
Maple, sugar	104.7	105.9	90.5	103.0
Oaks, all kinds	92.6	101.3	94.9	104.5
Poplar, yellow	67.3	93.8	41.5	37.9
	Conifers			
Fir, Douglas, Pacific Coast	95.7	122.1	59.9	58.3
Pine, loblolly	93.7	105.6	71.0	60.0
Pine, longleaf	112.2	122.1	77.7	74.8
Pine, shortleaf	94.1	100.6	69.7	64.0
Pine, Western white	75.5	99.7	53.8	37.0
Pine, Western yellow	67.0	75.6	42.9	41.0
Spruce, Sitka	69.5	94.1	63.3	44.9

NEW TYPE OF AIRPLANE PROPELLER

AN Englishman by the name of Bourke has invented a new type of propeller, which, it is claimed, will go a long way in lessening the noise and vibration caused by the existing type of airplane propeller. It is claimed by the inventor that his propeller by attaining the maximum thrust will increase the speed and at the same time require less engine power. Instead of being smooth, the blades of the propeller have a number of flanges made of aluminum raised about 6 in., which run in parallel lines across the surface and work just as the teeth of a turbine. With the new propeller the wash of the wind from the blades drives in a steady flow instead of striking the planes and struts in whirling gusts thereby increasing vibration. The grip of the serrated blades in the air is much greater and therefore a much higher speed is obtained in taking off. It is understood that the Handley-Page company contemplates making exhaustive tests of the new invention in the near future. One or two well-known pilots who have tried the new propeller privately are satisfied that it fulfills all the claims the inventor puts forth.—Air Service News Letter.

Flame

By C. A. French[1]

SEMI-ANNUAL MEETING PAPER *Illustrated with* DIAGRAM

STATING that the knowledge now available does not permit an exact scientific definition of flame and giving the reasons, in this paper the author regards flames as gases rendered temporarily visible by reason of chemical action, discusses their physical rather than their chemical aspects and, unless otherwise indicated, refers to the flames of common gasoline and kerosene only.

To gain a reasonably clear understanding of the requirements and characteristics of the different kinds of flame, it is necessary to begin with a study of atoms and molecules. The author therefore discusses the present atomic theory, the shape of the atom and molecular structure, and follows this with a lengthy detailed description of the beginning of combustion.

The requirements and characteristics of the inoffensive variety of combustion are considered next and nine specific remedies are given for use in accomplishing the burning of heavy fuels with a blue flame in present engines. Oxidation and flame propagation are then discussed, the statement being made and amplified that it is likely that kerosene and gasoline can be more effectively burned by stratifying the mixture so that ignition occurs in a very rich portion which burns out into an excess of air, or a supporting atmosphere.

THE present state of our knowledge does not permit of an exact scientific definition of flame, for the reason that it may be the result of either electrical, thermal or chemical action, or, perhaps, a combination of two, or all of them. Flame does not necessarily indicate combustion. The flames in the Moore tube, the Geissler tube or the mercury vapor lamp, do not arise from combustion; neither can their glow be attributed largely to thermal action. Solar protuberances, according to the common view, are gases whose glow is of purely thermal origin, but colorless gases in a tube cannot be made to glow by thermal action alone.

Combustion, either slow or fast, is not always accompanied by flame. Burning hydrogen and oxygen, if both are pure and dustless, make no visible flame even in the darkest room according to the experiments of J. S. Stas. This is consistent with the fact that the line spectrum of hydrogen lies wholly within the ultra-violet. In the combustion of ethylene and chlorine the attendant radiation is below the pitch of visibility. In catalytic flameless combustion, which may begin with the hydrocarbon mixture and catalyst below zero fahr. and end 2000 to 3000 or more degrees above, there is no flame whatever, nor does the catalyst propagate flame even when surrounded by an excess of very rich combustible mixture. Surface combustion, which is entirely distinct from catalytic flameless combustion, may be regulated so as to show no flame, but that is on account of the very great luminosity of the white hot refractory surfaces back of the transparent blue flame. It will always cause a visible flame if an excess of mixture is supplied. The cause of transparent flames is doubtless largely electrical, while the cause of the opaque luminous red, yellow and white flames is probably almost entirely thermal.

[1] Gas power engineering department, International Harvester Co., Chicago.

A consideration of these facts will show the present impossibility of a strict definition. For the purpose of this paper, flames will be regarded as gases rendered temporarily visible by reason of chemical action; their physical rather than their chemical aspects will be discussed; and, unless otherwise indicated, it will be understood that only the flames of common gasoline and kerosene are referred to.

Many combustion phenomena can be explained only by the assumption that in normal blue flame the fuel burns from the molecule. In explosive combustion present-day gasoline and kerosene refuse to burn with an entirely blue flame under the conditions we use them. They burn with a very objectionable luminous sooty flame, which causes detonation and carbon deposits; while lighter fuels of the same general character burn in an inoffensive manner and give much higher thermal efficiencies. To gain a reasonably clear understanding of the requirements and characteristics of the different kinds of flames it is necessary to start with a study of atoms and molecules. Dr. Irving Langmuir says of atoms, "If a lump of ordinary matter the size of a baseball could be magnified to the size of the earth, the atoms in it then would have become about the size of baseballs." Atoms are believed to be composed of charges of positive and negative electricity. The positive electricity is concentrated into a very small particle called the nucleus, located at the center of the atom. The negative electricity exists in the form of electrons which arrange themselves in space around the nucleus. The electrons in different kinds of atoms are alike, but there are as many different kinds of nuclei as there are chemical elements. These differ from one another only in the amount of positive electricity they carry. For the simplest element, hydrogen, the nucleus has a unit positive-charge which is able to neutralize the charge of a single electron. Thus a hydrogen atom consists of the nucleus and a single electron. The next element, helium, has a nucleus with a double positive-charge, and the atom thus contains two electrons. Atoms of carbon have six and oxygen eight electrons. The electrons are not stationary but each revolves in its own orbit about a certain equilibrium position. It is thought that all atoms occupy about the same spaces.

The Shape of the Molecule

As atoms are thought to be spherical, it is possible that molecules usually are of the same compact symmetrical shape; at least their behavior in combustion is best explained by this assumption. If we take any number of ½-in. balls less than 13, and arrange them in a symmetrical spherical form, it will be seen that none is entirely covered and cut off from contact with the outside. By taking 13 balls it will be found that there is one ball in the center that is entirely surrounded. As we know that nature abhors a vacuum, we imagine that there is one atom in the exact center of any ordinary stable gaseous molecule. We find that by starting with one ball, or atom, in the center we can arrange 12 more

around it so that all of the 12 will touch it. The arrangement will be symmetrical and the group will resemble a sphere. As there is no other equally symmetrical arrangement of spheres it is reasonable to assume that 13 atoms are the nucleus for any larger number. Hexadecane, $C_{16}H_{34}$, the largest molecule usually found in kerosene, has 50 atoms. Such a molecule would be likely to have 13 atoms inside and 37 on the outside. While 37 atoms would not quite symmetrically cover the 13 inside ones, if all of the atoms were rigid and unyielding, still there would perhaps be enough elasticity to the whole mass to allow the outside to be fairly symmetrical; there would therefore be three layers of atoms in such a molecule.

Molecules are thought to be vibrating and rather reacting on one another as they come near each other at rates depending upon their temperatures. In a mixture of combining proportions of air and fuel molecules the molecules of fuel, nitrogen and oxygen could bombard each other for days without starting oxidation, as it seems that some forms of chemical action between molecules are impossible. We know that two atoms, or one molecule, of hydrogen unite with one atom, or one-half molecule, of oxygen, and that one atom of carbon unites with first one atom of oxygen and the carbon monoxide formed by this union later unites with one more atom of oxygen. In other words a hydrogen molecule is satisfied with an oxygen atom, while a carbon atom requires an oxygen molecule but it can only use half of it at a time. It seems certain that the oxygen must be dissociated and ionized before combustion can begin. It is known that the radiation of a hydrogen flame is entirely in the ultra violet; that ultra violet rays dissociate and ionize oxygen; that oxygen ions spontaneously ignite many organic substances. Other means of producing oxygen ions will be discussed later, but as the blue flame of the electric spark we use for ignition is sufficient to ionize oxygen we are now ready to start the combustion of a 50-atom fuel molecule.

Beginning of Combustion

The electric spark ionizes enough oxygen to start the combustion of some one or more of the 37 atoms on the outside of the molecules. The ultra-violet rays from the burning of the first atoms ionize enough oxygen for the next few atoms but evidently not much more, for the blue flame never "runs away" or causes detonation as it would likely do if there were a large excess of ions. During the combustion of the outside layer of the molecule each atom is being bombarded by molecules of nitrogen and molecules and charged ions of oxygen. As the fuel atoms burn they send out new molecules of water and carbon dioxide, two first-class commercial fire-extinguishers, to replace the oxygen with which they united. If we imagine the atoms in the outside layer of the molecule to be about $C_{12}H_{25}$, there would be 24½ new molecules of carbon dioxide and water to replace the 18¼ molecules of oxygen used. The flame during the entire combustion of the outside layer of atoms is the perfectly unobjectionable transparent blue flame of almost entirely electrical properties with which every housewife is familiar from long use of it in the gas range or blue-flame oil-stove.

When this combustion started, assuming that there were no burned gases present from a previous explosion, each fuel molecule was surrounded with 93 N_2, and 24½ O_2, but when the 37 outside atoms have burned away we find 93 N_2, 12 CO_2, 12½ H_2O and only 6¼ O_2. It would be extremely difficult, if not impossible, to propagate a flame in a cold mixture of these proportions. A hydrocarbon flame cannot be propagated in an atmosphere containing less than 17 per cent of oxygen. With 117½ other molecules in the way, all of them the very best kind of fire-extinguisher, the 6¼ molecules of oxygen must have considerable time if they are to reach the remaining fuel atoms. In the meantime the 13 inside atoms have been subjected to the full flame temperature in the absence of air. If heated sufficiently in the absence of air all hydrocarbons will dissociate into hydrogen and lamp black. Probably some of the atoms immediately recombine into much smaller molecules; conditions at this time favor the formation of very small, highly endothermic hydrocarbons, such as acetylene, C_2H_2; but in any event there is much free hydrogen and free carbon.

Free carbon atoms tend to form aggregates of tangible size, far too large to burn quickly, among which the free nascent hydrogen burns heating them to incandescence. The flame now becomes first red, next yellow, then intensely luminous, opaque and radiant. The interstices between the solid carbon particles act as miniature refractory-lined reverberatory furnaces in which the free hydrogen is burned, thereby raising the temperature of the burning mass several hundred degrees. When the flame was in the stage of burning the outside layers or the blue stage only about 8 per cent of its energy was in the form of radiant heat; now more than 30 per cent of it is radiant.

When dissociation or cracking occurs at high temperature there is a large production of charged ions of probably all constituents of the mixture. A pressure wave, per se, probably could not be made to travel through molecular air in excess of the velocity of sound but charged ions undoubtedly greatly exceed that velocity. We will imagine that by this time one-quarter of the mixture is inflamed. The flame-front is still blue but the flame around the spark-plug, having been ignited first, has burned off the outside layers of the fuel molecules and has, by reason of the dissociation of the inside layers, arrived at the white-flame stage. Radiant heat with the velocity of light, and charged ions at something greater than the velocity of sound, are being sent out by the white-flame spot. The transparent blue-flame area between the flame-front and the white spot offers no resistance to the radiant heat and probably not very much resistance to the passage of the ions.

In air the vapor of hexadecane, $C_{16}H_{34}$, is very dense and opaque as the molecules are very large. Radiant heat is incapable of heating transparent vapors or gases, but it is absorbed in great quantities by a vapor as opaque as that of hexadecane. Heavy-hydrocarbon vapors when subjected to radiant heat of a moderate temperature will crack into smaller hydrocarbons when the cracking is done in the presence of enough air or neutral gas, but if subjected to radiant heat of a high temperature, if in the presence of air, they will ignite as they crack. Neither the radiant heat nor the charged ions can penetrate the dense cloud of vapor beyond the flame-front to a very great depth, but between them they instantly crack some of the molecules and ignite a very large quantity of highly compressed unburned mixture. This action causes a sudden severe increase in pressure, which, on a time and pressure diagram, shows a high peak occurring some little time after ignition.

This new flame very soon reaches the white-flame stage and causes perhaps another auto-ignition of a still more remote portion of the unburned mixture, causing a second pressure-peak. The more opaque fuel molecules would show a greater number of auto-ignitions or pressure

peaks than those of less opacity. It is easy to imagine that if a cylinder were large enough the pressures and temperatures would ultimately accelerate auto-ignition to a detonative rate of burning. Auto-ignition is often seen in forest and prairie fires where ignition occurs ahead of a flame-front when there is no possibility of sparks being carried to the area ignited. In experiments with burners auto-ignition is often seen when opaque vapor becomes ignited from a white flame some distance away with which the unignited vapor has no connection. There is little probability that a pressure wave causes auto-ignition as it would simultaneously ignite the whole body of unignited mixture, and we know that kerosene, for example, usually gives three pressure peaks, fuel oil five, etc., which seems consistent with the differences in the opacity of their vapors. There is no doubt that acetylene is occasionally formed and detonated. A glass window in the cylinder of a detonating engine on rare occasions shows a flash that is much more blinding; the noise is much louder than the ordinary detonation. Apparently this happens only with rich mixtures and an early spark.

It should not be imagined that the rate of oxidation increases after a dissociation, for such is far from being true. The rate of *inflammation* increases very considerably, but a careful study of the mixture proportions and ingredients after dissociation occurs will show that further oxidation, of the carbon at least, cannot be otherwise than a very slow process.

Before ignition there are 118 volumes of air, of which 80 per cent is inert nitrogen, with 1 volume of kerosene vapor. After the first 37 atoms of fuel are burned from each fuel molecule we have 1 fuel volume with 6¼ volumes of oxygen distributed through 117½ volumes of inert gas, hydrogen, carbon dioxide and water. We now have 1 fuel volume in 123¾ volumes of supporting atmosphere, but the fuel molecule is actually much smaller than the space it is vibrating in, and the supporting atmosphere is spread out to an enormous volume to include the vibrating space for its molecules. If we consider that the fuel vapor molecule is the ultimate mechanical division of the liquid fuel, then the actual volume of the molecule is proportioned to its weight. A 1-lb. molecule of kerosene requires about 338,000 cu. in. of air for complete combustion. After the combustion of the first layer of the 37 atoms of fuel, the atmosphere of the gases surrounding the remainder of the fuel molecule will occupy about 27,500 times the volume of the fuel, or a sphere of 30.2 times the diameter of the fuel molecule. The proportions are the same for a pound molecule, gram molecule or a single molecule.

Rich mixtures and unvaporized fuel greatly aggravate our combustion troubles. Inasmuch as it is positively known that hydrogen and carbon require definite quantities of oxygen for their combustion, it is not likely that we will ever be able to use rich mixtures, as we now use them, without undesirable complications. Unvaporized fuel has little opportunity to burn in a normal manner as by the time it is vaporized and ready to burn the oxygen supply is much depleted and the dilution with burned products makes it exceedingly difficult for the oxygen to reach it in time to oxidize any of it before dissociation occurs.

Inoffensive Combustion

Having studied a very inefficient type of combustion, we should now study the requirements and characteristics of the inoffensive variety. It should be understood that unless complete dissociation occurs immediately previous to ignition, any kind of a visible hydrocarbon flame cannot be propagated without an initial area, or period, of transparent blue flame, in which the air and fuel are in explosive proportions. Whether the fuel is burned in a supporting atmosphere, as a homogeneous explosive mixture, or even in a complete inversion of combustion, i. e., the burning of air in an atmosphere of fuel, makes not the least difference with the flame characteristics or color in the initial area or period. Entirely green, lavender, red, yellow or white flames cannot be propagated except as above stated, nor can they be maintained if too widely separated from transparent blue flame. If a yellow flame is examined through a yellow color-screen, it will be found to be permeated with a thin blue flame, and if a supporting atmosphere is available it will be seen that the yellow spot is entirely surrounded by blue flame. This is also true of spots of green, red and white when examined through the proper color-screens. In the oxidation of stable fuels spots of green, red, yellow or white indicate either a temporary or a permanent lack of oxygen, and the fuel atoms that actually cause spots of those colors are not at that instant burning. Hydrogen makes no visible flame; nor does carbon in burning to carbon monoxide; carbon monoxide usually burns with a transparent blue flame; therefore, a transparent blue flame is the only *visible* sign of oxidation. Spots of any other color indicate the cracking of the fuel into new smaller hydrocarbons and the large production of carbon monoxide, or the complete dissociation into free carbon and free hydrogen.

In the blue flame the reactions are simpler, more complete and the flame is more compact than any other. The molecules are in more rapid vibration and the oxidation is completed in much less time than when dissociation occurs. It has only about 8 per cent of its energy in the form of radiant heat, it is incapable of depositing soot, and its progress is not seriously affected by contact with cold surfaces. The only known requirements of blue flame are enough air and a fuel that will remain in the molecular state until fully oxidized. Nearly all liquid and gaseous hydrocarbons can be burned with an entirely blue flame, but, beginning with molecules of 12 atoms, more time for the burning must be given as the molecules become larger. Leaving out the ethers, the acetylenes and a few other hydrocarbons that are incapable of burning without more or less explosive dissociation, it can be said that any fuel molecule of 12 atoms or less will burn with an entirely blue flame under any pressure so long as there is no excess fuel.

There is, of course, what might be called a gradual decomposition of the fuel molecule even in a normal blue flame. Products of a limited oxidation of kerosene by catalytic flameless combustion are composed of a large number of alcohols, aldehydes, acids, and saturated and unsaturated hydrocarbons. In the green area of the Bunsen flame there is a very great amount of cracking into new molecules but so long as complete dissociation does not occur the flame does not become luminous. In the so-called wickless blue-flame kerosene-stoves small jets of air are burned in an atmosphere of kerosene vapor until the fuel molecules are cracked down so small that they will burn above the stove in a supporting atmosphere without luminous flame. It is apparently impossible to produce complete dissociation when enough air or neutral gas is present.

Fuels of the benzol series can seldom be made to burn explosively with a white flame unless a great excess of fuel and very high compressions are used. They can be caused to dissociate and make a cloud of black fluffy carbon, but as benzol series molecules are all small, they

do not dissociate until practically all of the oxygen is used; there being very little oxygen left after dissociation, the free hydrogen usually cannot burn enough to heat the carbon particles to incandescence. Used in stoichiometrical proportions such fuels probably cannot be made to detonate under any pressure. Fuels of the saturated series, when used in excess, have more tendency to become luminous; they are almost certain to have some large molecules as they are nearly always a mixture of a large number of different members of the series.

For every fuel molecule larger than 12 atoms there is a rate of oxidation that will cause it to dissociate, but for use in present explosive engines a molecule of 20 atoms or less would burn fast enough to be perfectly satisfactory, provided that there were no highly endothermic bonds in it. Its vapors would be so nearly diathermous that they could not be much affected by radiant heat. Fuels having the largest molecules have the most opaque vapors. The large molecules cannot burn rapidly without dissociation. The excess of ions from the dissociation and the radiant heat from the incandescent free carbon particles cause auto-ignition in unignited portions of the mixture. Therefore, to burn heavy fuels with a blue flame in present engines, one or all of the following remedies should be used:

(1) Thoroughly vaporize fuel
(2) Retard speed of oxidation
(3) Crack opaque vapors before ignition by use of radiant heat
(4) Raise compression and use reasonable excess of air
(5) Ionization previous to ignition
(6) Induce great turbulence
(7) Destroy reverberatory action of combustion-chamber walls
(8) Eliminate pockets in the combustion chamber
(9) Locate spark-plug in exact center of combustion-chamber

Oxidation and Flame Propagation

Oxidation can be retarded by careful cooling of the combustion-chamber, and by the use of plain diluents such as an excess of air or cool exhaust gas. The compression should be high, 125 lb. or more, to gain in thermal efficiency. The diluents can then be used with more effect and economy than when the dilution is secured by lowering the compression. It might be worth while to try a very small amount of chlorine as a diluent, as this substance is an ionizer and whenever a hydrogen atom is freed from a molecule, leaving the molecule in an unstable equilibrium, the chlorine would be likely to replace the hydrogen and preserve the molecular structure.

To best promote flame propagation the oxygen might be ionized by some of the catalytic processes. Great turbulence also accelerates inflammation and aids in keeping temperatures down by the scrubbing action of the burning gases upon the cold walls. To decrease the noise of detonation and to prevent extremes of temperature the combustion-chamber should be without pockets and very compact, *but without parallel surfaces*, so that neither heat nor sound can be concentrated by reverberatory action. The spark-plug should be located so as to give the flames the shortest possible travel.

It is likely that kerosene and gasoline can be more effectively burned by so stratifying the mixture that ignition occurs in a very rich portion which burns out into an excess of air, or a supporting atmosphere. If properly done detonation could not occur as the fuel would occupy but a small place in the combustion-chamber. Being a very rich mixture the rate of inflammation would be high. Complete dissociation would not be likely to occur and could not cause auto-ignition if it did, as there would be very little opaque vapor beyond the flame-front. A well vaporized very rich mixture burns first blue, then green, the green indicating a cracking into new smaller hydrocarbons. If enough air is available immediately after the cracking the green flame becomes blue again and is in no way objectionable except that it is about 50 per cent more radiant than the blue flame. With this method the air is not throttled; the fuel only is governed. An engine using this method of combustion would have steam-engine characteristics in a reasonable degree, without sacrificing economy, which is much more than can be said for present engines.

THE DISCUSSION

O. B. Zimmerman:—To my mind, Mr. French's paper is one of the most constructive that has been presented to the Society. It is hardly to be expected that in this first approach to a subject on which the state of our understanding is still very vague, or at least on which the data concerning the phenomena are not well dispersed, the data will be correct according to the understanding of certain individual technologists, but we must admit that this paper does open up a vast and necessary field for study and research along chemical and physical lines. Until we can form correctly a clear understanding of the structure and characteristics of the medium we are dealing with, we shall not arrive at the best results. Should a doctor have a case of smallpox that he treats as measles, he might arrive at a cure but still not do it in the best way. As engineers, altogether too many of us are endeavoring to solve the problems of the internal-combustion engine in a purely mechanical way, without due consideration of the physical and chemical requirements of the medium with which we are dealing.

Credit must be given to Mr. French for the deductions he has given us from a careful review of the subject. The paper is particularly illuminating in enabling us to visualize the probability of the method of flame propagation, the peculiar mixing of burnable and burned gases during this phenomenon, the probable effect of the shape of the container, the dispersion of heat and pressures and, finally, the combined effects of these mixed activities on efficiency. Another feature that it emphasizes is the undoubted probability that if the refineries will devote more attention to an endeavor to produce liquid fuels with regard to the real requirements of an engine, such as a fuel of a simple series of molecular structures rather than those having a wide range of complex structures as we often have today, both fuel producers and consumers will be benefited. That such a simple structure is possible in a thoroughly commercial way is being demonstrated today in a going refinery. The results show that the structure of the molecules as arranged in a paraffin series is not necessarily the best one for the economical operation of the internal-combustion engine. It is possible commercially to rearrange this structure by chemical means, thus making a more efficient fuel than we have now. If we are then really to develop the internal-combustion engine into its most economical and practical form, we must delve into the science of the unknown, as Mr. French has done.

Prof. Robert E. Wilson:—I wish to thank Mr. French for stimulating thought on the subject of just how flame is propagated. I, for one, am planning to make some experiments soon which should tend to verify or refute his conclusions. I believe Mr. French will admit that his theory of flame propagation is but an hypothesis unsup-

ported as yet by sufficient experimental data to warrant our acceptance of it without further question. Furthermore, a number of statements are made in Mr. French's paper which appear to demand correction.

Atoms and molecules are real things; they exist. The mere fact that we cannot see them is no reason for not taking all the evidence obtainable from a variety of sources and making the best possible working drawing of their structure. To do without definite pictures of atoms and molecules is just as much of a handicap for the chemist as it would be for an automotive engineer to try to construct an engine on the basis of a hazy idea instead of accurate drawings. Unfortunately, the working drawings of atoms and molecules that Mr. French has presented do not fit in with certain of the known facts with regard to their behavior. For instance, the statement "it is thought that all atoms occupy about the same spaces" is not reasonable from what we know of the constitution of matter. When the number of separate electrons in the atoms varies from 1 in the case of hydrogen up to 92 in the case of uranium, it seems impossible that the volume could be the same. As a matter of fact, on the basis of practically undisputed measurements and calculations it is known that there is a variation of *at least* fivefold between the volume of the smallest and the largest atom.

Proceeding from the atom to the group of atoms, or molecule, which is the characteristic unit of all our chemical compounds, Mr. French postulates a type of molecule that is merely a group of spheres of uniform size tied together very much like a bunch of grapes, the spheres all being bound close together in concentric layers. Now we do know definitely, for reasons that Dr. Langmuir of the General Electric Co. has explained very clearly, that these molecules are not arranged in any such casual grouping, but that each atom is tied to one or more others in a certain definite fashion. Also, we know whether the resulting structure is a straight chain, a branched chain, or a ring with or without branches. Unfortunately, Dr. Langmuir has not as yet gone into the structure of very many organic compounds, but, simply by applying his theory to organic compounds, E. C. Crocker of the research laboratory of applied chemistry at the Massachusetts Institute of Technology has found it possible to work out very definite structural formulas. The upper portion of Fig. 1, for example, represents a molecule of normal hexane, one of the low-boiling constituents of gasoline, except that on paper the cubes representing the carbon atoms can be pictured best as squares. These cubes should not be conceived of as solid material, but as models the corners of which indicate the positions of the electrons in space. In the figure the corners of the squares therefore correspond to *pairs* of electrons, in two planes, one above the other, that are held in common between two atoms.

We can say, then, for purposes of visualizing the stresses involved, that in a molecule of normal hexane we have six carbon atoms attached end to end, making a straight chain characteristic of the paraffin hydrocarbons. The hydrogen atoms are much smaller and are attached to the free corners. Now we definitely know that this chain is not normally bent or tied in a knot, although it is not a rigid body. If anything hits such a molecule, it will bend like a piece of spring steel. These hydrogen atoms, having light, positive charges, tend to repel one another and it takes a great amount of force to bring them together. Such a structure is obviously far different from the disordered mass of tightly packed spheres postulated by Mr. French.

Probably Mr. Crocker's most important contribution is in his representation of the structure of benzol. It also has six carbon atoms joined together, but in this case they are in the form of a ring, which can best be represented on paper as at the bottom of Fig. 1. Here each corner of each triangle represents a pair of electrons held in common between two atoms and the dots represent small electrons vibrating in the plane of the ring.

I wish to thank Mr. French for suggesting an explanation of our getting a luminous flame when we have a long molecule. He says that we burn off the outside carbon and hydrogen atoms and that this heats up the inside ones. That is not true, because they are not packed together in the way which he postulates. If, however, we take a straight chain, such as that pictured in Fig. 1, the hydrogen atoms are on the outside where they can combine with the oxygen, and they are obviously the first thing that burns. Now we have much evidence that oxygen cannot force itself in between the carbon atoms in such a chain. The carbon atoms must therefore burn only on the free end. Obviously, if we have a long chain, we burn off the hydrogen atoms instantly, and then we start to burn the chain of carbon atoms from each end. If this chain is long enough, it is likely to combine before it is completely burned with other similar carbon chains that have been stripped of their hydrogen, thus forming tiny solid particles of carbon made luminous by the heat of the combustion. This gives us a very definite picture of why a long chain behaves so differently from a short chain. There is, however, no sharp change as postulated by Mr. French when the number of atoms exceeds 13, the number which would be in his inner layer or nucleus of spheres.

The statement in Mr. French's paper that "one atom of carbon unites with first one atom of oxygen and the carbon monoxide formed by this union later unites with one more atom of oxygen" is also contradicted by the best evidence available. The Bureau of Mines has definitely shown that under ordinary conditions of combustion one atom of carbon combines directly with one molecule of oxygen containing two atoms. Then when the carbon dioxide goes on up through the hot fuel-bed, another atom of carbon is likely to grab one of the oxygen atoms from carbon dioxide, forming two atoms of carbon monoxide. Reasoning on the above basis, Mr. French has suggested that if combustion is to take place, it is first necessary to divide the oxygen into atoms. This conclusion is certainly rendered less secure by the evidence that carbon does combine directly with a full molecule of oxygen according to the best evidence available.

The statement is made that "a hydrocarbon flame cannot be propagated in an atmosphere containing less than 17 per cent of oxygen." That depends on the temperature and pressure to a very considerable extent, but even at an ordinary temperature acetylene will explode without any difficulty in a mixture containing much less than 17 per cent of oxygen; in fact, I have exploded mixtures containing as low as 6 per cent of oxygen.

F. C. MOCK:—Will Professor Wilson please continue his explanation as to what happens to the chain molecule during cracking, as well as at the initiation of spontaneous combustion, if such a thing occurs? In the latter case, for instance, whether the carbon burns off the end of the molecule or the molecule breaks in the middle.

PROFESSOR WILSON:—I should have said that while oxygen cannot pry itself in between the carbon atoms in that chain, it is nevertheless possible that a long chain that is, of course, in constant violent motion will break

at high temperatures; then it is free to oxidize at several points. So, the cracking that we get, or the breaking down into smaller units, would tend to make a less luminous flame.

As to what happens in spontaneous combustion, it is simply a question of reaching the ignition temperature, which can be accomplished in a variety of ways. There is no difference between spontaneous combustion and any other kind of combustion. A temperature is simply reached where the compound is oxidizing rapidly enough to propagate a flame.

Mr. Mock:—It seems that the larger the molecule the more nearly the temperature of spontaneous combustion approaches that for cracking. Is it not highly probable that the two kinds of action will occur almost at once during what we call detonation? I mean that when a temperature is reached in the cylinder where one would occur, the other also would occur.

Professor Wilson:—I am not familiar with the precise facts, but it is certain that the ignition temperature of many of the products of cracking is considerably lower than that of the original large hydrocarbon molecule. It is therefore entirely reasonable to expect that on heating certain large molecules with air, cracking would begin before combustion, and that the very active smaller molecules thus produced would almost at once start to propagate a flame.

Chairman Thomas Midgley, Jr:—There is a general relationship between auto-ignition and cracking temperatures but there are exceptions to it which prove that they cannot be exactly the same things.

Since reading Mr. French's paper we have experimented with the effect of chlorine upon the knock and find that chlorine is a very bad knock-inducing material, which is quite contrary to the prediction made by Mr. French.

C. A. French:—My statement was not intended to imply that atoms are compact. The modern conception of the atom is that there is a positively charged nucleus surrounded by one or more negatively charged electrons. The electrons are at comparatively immense distances from the nucleus. This distance is probably fixed by their charges. As the nucleus has a unit charge for each electron, there is no good reason for believing that these charges are not all equal and that, regardless of the size of the atom, the electrons will always keep about the same distances from the nucleus, especially as there is more than ample room for them to do so, and as the repelling action of their negative charges would keep them from colliding. This would make all atoms occupy about equal spaces. I can imagine a hotel having 100 rooms, all of the same size, but each inhabited by a person of a different size from any of the others. Thus the 6-lb. baby or the 600-lb. giant would each have space enough in which to move about freely, but each would live in, occupy or inhabit equal spaces without actually filling the space he used.

Just what a molecule looks like no one knows, and perhaps no one will ever know. Many eminent physicists, chemists and scientists are accustomed to think of molecules as being spherical in shape. In the absence of any proof to the contrary we are entitled to assume that they are spherical if this explains best why a large molecule must burn slowly if it is to escape dissociation. Without denying that the atoms in a molecule are tied together in very definite chain formation, as Professor Wilson states, it would still be easy to bunch almost any kind of a long chain into a sphere, and almost any link might be left on the outside. This seems more consistent with the tendency of matter to assume a compact shape. Carbon,

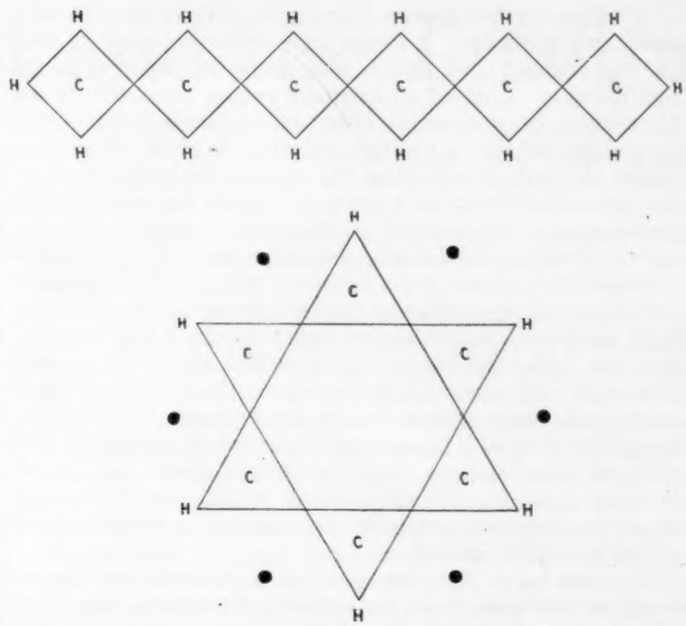


Fig. 1—The Chain Structure of a Molecule of Normal Hexane Is Shown in the Upper Portion and Underneath the Ring Structure of a Benzol Molecule

when freed from the molecule, forms spherical aggregates that can be seen with the naked eye. Happily the extended chain conception of the molecular structure serves about equally well in proving that a certain amount of time is required to burn a large molecule without dissociation, which is the point that I particularly want to emphasize. For some reason oxygen cannot get to all of the atoms of the molecule *in time* to save them from dissociation if oxidation is too rapid. If we assume that the molecule exists as an extended chain the combustion would likely begin at each end and as it progresses toward the middle the dilution of the oxygen with water, carbon monoxide and carbon dioxide becomes greater, so that a certain amount of time must be allowed for the oxygen to reach the remaining fuel atoms. If the dissociation is extensive enough it produces auto-ignition in the unburned mixture ahead of the flame front. The new flame soon reaches the stage of dissociation and produces another auto-ignition. If a cylinder were large enough and long enough the velocity of propagation would finally reach a rate that would be limited only by the time necessary for the radiant heat and the charged ions to propagate flame, a rate certainly far in excess of the velocity of sound. Mallard, Le Chatlier and others are in fair agreement that the velocity of detonation in a long closed tube is 3500 to 3700 meters per sec. (11,482.92 to 12,139.08 ft. per sec.).

Experiments with gas turbines with the gas at very high temperatures and pressures have never shown that the gas cannot be made to move through a nozzle faster than the velocity of sound in the same mediums at the same temperature and pressure. Apparently, no nozzle velocities remotely approaching 3500 meters per sec. (11,482.92 ft. per sec.) have been reported. The Midgley indicator-cards show one detonation peak for Pennsylvania gasoline, three for kerosene and five for fuel oil burned in the same engine, thus showing one, three and five auto-ignitions. A pressure wave could produce but one peak in any fuel, and it could not travel 3500 meters per sec. (11,482.92 ft. per sec.). As we cannot make molecular air move faster than sound, it is certain that detonation is not directly due to pressure.

Whether carbon burns directly to carbon dioxide is a debatable question. I would like to believe that it does in the normal blue flame, but there is much evidence against this. Linseed oil annually causes hundreds, if not thousands, of fire losses from spontaneous combustion. In drying, which is really oxidizing, it gives off carbon monoxide and, in splitting the oxygen molecule to form the monoxide, liberates a charged oxygen ion which sometimes causes spontaneous combustion. Other hydrocarbons in the process of slow oxidation are prone to ignite spontaneously under circumstances that preclude the possibility of their ordinary ignition temperatures having been reached. Investigation seems to show that oxygen ions are invariably produced as a first step. If oxygen ions were produced as a first step, certainly carbon monoxide and water would be the next things to look for. Knox Harding of Chicago told me that he prepared 100 different combinations and that within three months 48 of them ignited. All of those in which the production of oxygen ions was arranged for ignited; none that were not so arranged ignited.

My statement that no kind of a hydrocarbon flame could be produced in an atmosphere containing less than 17 per cent of oxygen should have been qualified to the effect that a hydrocarbon flame can be produced only when there is a large number of ions following a dissociation or considerable decomposition in which there is really less of oxidation than decomposition. Even under such circumstances it would be impossible to propagate a flame with most fuels without a catalyzer or a very hot refractory surface. However, in any discussion of flames and possible mixture proportions it should always be understood that acetylene, ether and catalytic flameless combustion are excepted. Berthelot and Vielle found that liquified acetylene under 150-lb. pressure would explode with a brilliant flame, producing a pressure of over 5000 atmospheres without any air or any other supporter of combustion, but this was explosive dissociation without oxidation. It is different to burn acetylene explosively without much more explosive dissociation than oxidation.

Ether is a C_2H_5 radicle on each side of an 0. Its vapor-tension boiling point and some other things are more characteristic of one of the radicles than of the molecule, showing that there is such a lack of cooperation between the radicles that we should expect it to have unusual properties. A very rich mixture of ether vapor and air, forced by 10-lb. or more pressure through an expanding nozzle into an exhausted tube 4 to 8 ft. long, dissociates and ignites at extremely low temperatures. Mixtures much too rich to ignite under ordinary circumstances are easily ignited by this method. Catalytic flameless combustion can be maintained with mixtures as rich as 2 to 1 by weight, but there is a very great amount of cracking and little oxidation.

I regret that the discussion has not brought out more ideas on the type of flame that should be used; for very definite reasons some types are preferable to others. We should decide upon the type and then learn how to produce it. Reports of investigations of combustion in closed cylinders usually fail to mention flame colors and characteristics, without which the reports are of doubtful value.

THE AUTOMOBILE INDUSTRY

SINCE the beginning of the automobile industry in America, 25 years ago, the number of cars manufactured up to the beginning of 1921 has been about 11,775,000, of which more than 700,000 have been exported. About 9,000,000 are in use, and 2,000,000 have been worn out, destroyed or abandoned.

The average term of service based upon the most authoritative statistics available has been about six seasons.

By the end of 1920 there was one car in use for each 12 people in the population.

The theoretical number of possible purchasers of motor vehicles seems to be limited to about 20,000,000. This is about the number of white, native-born men above the age of 21. It is also about the number of white American families. It is also about the number of persons earning money whose occupations are such as to make it appear possible that they might become motor-car owners.

At the end of 1920 there were about 42 cars in use for each 100 native white men of voting age. The number varied in different parts of the country from about 22 cars per 100 men in the East South Central States to 60 cars per 100 men in the Pacific States.

It seems impossible to compute any saturation point for the industry because the number of cars demanded will apparently depend for many years to come on the general prosperity of the country.

It appears certain that for some years to come new users of automobiles will largely be people of limited means who will purchase inexpensive cars.

Since 1916 the increases in the annual output of automobiles have largely been accounted for by the expanding output of Ford cars and of other relatively inexpensive makes.

Up to the present time the replacement market has never exceeded 500,000 cars in a year, but there is every prospect that it will shortly amount to at least 1,500,000 cars per year.

Present productive capacity of the automobile industry is more than 1,000,000 cars per year greater than would be required to maintain the existing use of machines in a constant status.

Unless exports of cars increase enormously it appears that the present productive capacity of the industry would be sufficient nearly to double the number of cars in use within the next few years. It appears extremely doubtful if foreign or domestic markets can be sufficiently expanded to take care of this capacity, and if they could it seems probable that some motive power other than gasoline would have to be developed to propel the cars.

It seems probable that extensive price adjustments will be made in the next few years, as the industry, with its great capacity, competes for purchasers among people and countries whose buying power has recently been sharply curtailed.—Leonard P. Ayres, Vice-President, the Cleveland Trust Co.

The Metallurgist and the Tractor

By C. S. Moody[1]

Minneapolis Section Paper

The author considers first the materials available for construction, in connection with the S. A. E. standard specifications, and presents a comparison of the different metals with comments thereon. In regard to metallurgical problems the designer's first task is to determine what the various stresses in the parts are and their magnitude; hence, a true appreciation of the terms "shock" and "fatigue" is necessary; a somewhat lengthy explanation of their meaning is given.

The construction features of the different parts of the tractor are treated in general, no attempt being made to cover details; comments are presented on front axles, wheels, bearings, cylinders, valves, valve-seats, transmissions and gears. Heat-treating is then considered in some detail, three specific reasons for annealing before machining being given and five which are governing factors in regard to heat treatment in general.

I WILL not attempt a paper that is an original thesis but instead present bits of information gathered from time to time. This information is offered more with the idea of starting an argument than of imparting details and all thoughts herein set forth are expressed from the viewpoint of the tractor builder.

Materials

The standard specifications issued by the Society of Automotive Engineers suffice as a beginning for this address and we can use them as a foundation on which to build the remainder. A brief synopsis of our present knowledge put into a slightly different form may not be amiss. I refer to a paper[2] by Ira T. Hook of the General Motors Corporation entitled Factors Limiting the Use of Materials. Imagine a prismatic bar supported vertically at one end and extended to such a depth that its height or weight is sufficient to cause fracture. Then the length in feet equals the tensile strength divided by 12 times the weight per cubic inch. Table 1 gives us a fair idea of what we are working with.

TABLE 1—COMPARISON OF DIFFERENT METALS

	Length in tension, ft.	Length in compression, ft.
Cast Iron	6,400	32,000
Common Steel	15,000	30,000
High-Grade Alloy Steel	59,000	88,000
Hard-Drawn Copper	13,100	18,400
Duralumin	28,000	40,000

The proper uses of the various steels is a large study in itself. The tractor industry as a whole views steel as steel and alloy steel as alloy steel, no more and no less. The point I make is that alloy steels have characteristics which make them applicable to certain kinds of work. For example, we use S.A.E. No. 2330 nickel steel for shafts and parts which undergo deflection from the stresses applied, but we want high-carbon steel helped out with chromium on wearing surfaces. So much for the necessity of intelligent specifications. I assume that all are familiar with the S.A.E. standard steels; there are, however, one or two cases in tractor work where we must go outside of them as for example manganese steel castings.

Cast steel in the heat-treated condition has proved very successful for tractor parts, principally gear blanks, crawler treads, steering-arms and front axles. The common objections to cast steel are blowholes and shrinkage. They are foundry problems and excessive unsoundness should not be tolerated in vital tractor parts. For example, we use a 90-lb. heat-treated tractor gear that is heavily stressed. Thousands of these gears have been received and in the case of the company that supplied 90 per cent of them there have been no rejections and not over 10 had perceptible shrinkage or blowholes. This was purely a matter of foundry practice, which has been worked out satisfactorily to all concerned.

At present a number of firms are selling cast alloy steel that shows physical properties far above those of mild rolled or forged steel. After heat-treatment one well-known brand, composed of 0.40 per cent carbon, 0.35 to 0.45 per cent chromium and 1.25 per cent manganese, shows a 90,000-lb. tensile strength and will bend double. Another 0.30 per cent carbon, low chrome-nickel alloy will show 65,000 to 75,000-lb. yield point, 95,000-lb. tensile strength, an elongation of 16 to 19 per cent and a reduction of 25 per cent or over after heat-treatment. Other alloys with 2 to 3 per cent of nickel and 0.30 per cent carbon show about the same tensile properties.

With these physical values, together with the accompanying hardness, large slow-speed gears impossible to forge give fine service. The necessity for extreme hardness does not seem to be manifest with cut gears and enclosed lubrication in our newer tractor jobs. I will not discuss gearing more than to say that based upon our experience we have in the order of increasing wear cast iron, cast steel and manganese steel.

In large reduction gears we find that cast steel used in the carburized condition has proved very successful because, with intelligent handling and the generous sizes necessary for surface wear, we can do practically all that it is possible to do with forged steel, in spite of the larger grain-sizes generally prevailing in cast steel. In my personal experience I cannot recall one breakage in heat-treated cast-steel gears that is attributable to large grain-size as such. The shock properties of cast steel cannot equal those of forged steel but, when good judgment is used, this does not appear to be a hindrance until we get into the intensive type of tractor design.

Manganese steel is not used by the automobile engineer but is commonly met with in tractor design. It is used mostly in treads for crawlers and in drive pinions. It will show about a 56,000-lb. elastic limit with 105,000 lb. as a maximum, a 34-per cent elongation and a 35-per cent reduction of area. This steel, while ductile, resists abrasion to a marked degree. It cannot be machined, but must be ground, and is admirably suited for use for external or unprotected gearing; it runs well without lubrication in sandy or dry soil.

Malleable-iron castings, when carefully made and inspected, perform creditably in the place of untreated drop-forgings but, when put through many foundries on

[1] M.S.A.E.—Metallurgical engineer, Minneapolis Steel & Machinery Co., Minneapolis.

[2] See Transactions of *American Society for Steel Treating*, November, 1920, p. 140.

a production basis, the individual care seems lacking and breakages occur which do not manifest themselves in forgings. I have in mind shifter levers and front axles. Where the machining to be performed coincides with the sections most likely to show shrinkages and defects, malleable iron works very well, as in this way a real 100 per cent inspection is obtained.

Metallurgical Problems

The designer's first metallurgical problem is to determine what the various stresses in the parts are and what their magnitude is. This leads us into a true appreciation of the terms "shock" and "fatigue," which are ever-present in automotive design. Let us first look at the fracture of a failed part and see how it occurs. We have what is known as the elastic limit. The definitions for "elastic limit" or "working elastic limit" are numerous, but the failure is initiated when the first crystal in some isolated portion of the piece will no longer return to its original position after being stressed. The common method of determining the "true" elastic limit or yield-point is to stress the piece in tension and in compression. The highest stress that can be applied and still permit the piece to return to its original length is taken as the elastic limit. This is not the same point when either tension or compression is applied alone. Undoubtedly, the first slippage of the crystals occurs before the elastic limit is apparent as measured in usual tests.[3] We know that materials do break or fracture when repeatedly stressed below their elastic limit, as ordinarily termed, and we know, further, that the more closely their reversals in stress approach the common elastic limit in magnitude, the fewer are the number of reversals required to produce fracture. So, we see that the true elastic limit varies with the number of 100,000 times the reversal of stress is made.

When we have a service fracture that shows a series of rings arranged concentrically about a point, we call it a progressive or "fatigue" fracture because it extended over a relatively long period of time and resulted from repeated applications of stress within the apparent elastic limit; no one of the loads applied to the piece *by itself* could have produced failure. Consequently, for this repeated or repeated-and-reversed stress we desire a metal with high elastic limit. Because we get a high elastic limit, we usually get low ductility, that property which allows the metal to deform under load. We know that such a type of steel will not withstand sudden shocks. These shocks resolve the steel into one that will absorb work. From the simple laws of mechanics we know that, excluding the heat generated, work is the sustained exertion of pressure through space and is equal to the force multiplied by the distance traveled. If this is the case, sudden isolated loads do not of necessity need a high elastic limit, because we want the metal to deform and absorb these isolated shocks, and still retain the piece. With this understanding, we must weigh our problems and balance the shock properties against the fatigue properties of metals. The essential problem is, then, what are the real operating stresses? In this connection the fracture of broken parts often leads us to the proper solution of future problems. If one is particularly observant, this may save the firm many dollars; for example, in making unnecessary the replacement of a broken crankshaft for a 7¼ x 9-in. engine that has been improperly rebabbitted in the field, thus causing a deflection to recur repeatedly that results ultimately in a progressive or "fatigue" failure.

There is another feature that is too often overlooked in the tractor field, due to the fact that small production and local sales do not make the trouble evident in its proper magnitude, or as quickly as when the machine is operated under adverse conditions. Neglecting the notch effect is the engineer's greatest failing. The designer will literally spend days on a design and then leave a notch in a vital section of the finished work that will wreck his whole machine. One glaring example of the stresses that may be so produced is given in Handbuch der Materialienkunde für den Machinenbau, by Martens and Heyn, Vol. 2A, page 364. The investigator took a solid square bar of lead, notched it and broke it by impact from the solid side. He did this also with another unnotched bar. The volumes of the strained parts were as 1 to 3.76. The elongation was measured by 5-mm. (0.197-in.) squares made before fracture; they showed 120 and 70 per cent respectively for the notched and unnotched bars. But the real value of the localized stresses caused can be shown by the line at the bottom of the notch which, originally about 0.25 mm. (0.00984 in.) wide, was increased to 4.25 mm. (0.2382 in.) in width or 1700 per cent. The engineer should beware of notches.

The coefficient of expansion of different metals is too often neglected; the values of this coefficient at high temperatures are all too meager in our handbooks. As tractor engineers using kerosene-burning engines, we should look at the sections of cylinder-heads and see how the expansion can take place. Likewise, let us look at the sections of heat-treated gears and be sure that they can be heat-treated successfully on a production basis. We can generally accomplish almost anything in the tool-room at least once. In this connection, let us not depend on laboratory tests for strength and hardness when we work with 2-in. sections and test on a 1 or a ½-in. section. Nor should we depend wholly on the S.A.E. standard curves. I did this and had the painful experience of having "tonnage" steel bought for me which met all of the chemical specifications but failed to have the desired physical properties, as a number of expert steel service-men can testify. I allowed for the size, which was 3½ in. to be exact, but did not allow for the quality or rather the lack of it, as the instructions in the S.A.E. Handbook state that the values given should be obtained without difficulty or that they are average values. The thought that I received from reading the instructions was that with average practice the results mentioned should be duplicated. We used the best practice, including preliminary heat-treatments, without any effect.

In our heat-treating we find further that the critical ranges of the various alloys have a marked effect on warpage and distortion. It can be said in a general way that the higher the alloy is, the less the warpage is and the less is the care that must be used in heat-treating. We find that in tractor sections that we have to use water for quenching, whereas the same steel for automobile sections can be quenched in oil.

Construction

In taking up the different parts of the tractor for individual examples, I do not aim to cover any details. We find frames made of cast iron and cast steel, as well as of rolled-steel sections. The use of pressed-steel frames is limited, pressed-steel parts being generally confined to hand-hole covers, valve-covers and base-pans.

The front axles are mostly drop-forgings, there being

[3] See Introduction to the Study of Physical Metallurgy by Walter Rosenhain, pp. 254-255; also an article by the same author entitled Engineering Relations of Shock and Fatigue, published in *Automotive Industries*, June 10, 1920, p. 1293.

a few built-up types. There have been some short-lived examples of cast-iron and malleable-iron axles. Cast-steel axles are being discarded because of blowholes that cause fractures. Few of these types have been heat-treated. For small production, cast steel produced by a first-class firm and heat-treated should be given first place, with the drop-forged untreated front axle for high production. I say untreated because I favor the larger section modulus in a tractor running-gear. The latter applies also to drag-links and steering-arms, which nevertheless should be heat-treated and designed for shock properties. In steering-knuckles we find a fairly general tendency toward anti-friction bearings, with little foundation for it other than automobile practice. We have produced our small tractor successfully without them, after eliminating some slight difficulties. Where we originally took care of wear by carburizing, we had fractures showing both fatigue and shock as having been the cause. Later we carburized the wheel bearing only and eliminated the trouble to some extent. Now we are using S.A.E. No. 3140 steel, which we feel gives an even better job on account of production as well as service.

I feel that the design of tractor wheels opens the largest field for the consideration of better materials. No one has to our knowledge given the wheel the scientific study it deserves. As I have heard it expressed, "Any fool can design a wheel"; many of them have done so but, if the history of the tractor industry were written, more failures would be found in the wheels of so-called successful tractors than in any other part. Tractor wheels support, first of all; they must do that, but how many operators consider the stresses they put on front wheels in cramped positions, as they apply full power in turning in a soft field? Yet the user in many cases expects a gratis replacement if failure occurs.

Wheels that will stand up can be built with less weight. Then, too, spokes break from fatigue. Let us have light wheels of good material amply fastened and supporting the rim. The same result can be accomplished by using a heavy rim; I venture the opinion that 75 per cent of wheel troubles can be eliminated by stiffening the rim.

In tractor engines there are one or two parts that come in for a great deal of trouble not encountered in automobile engines. Lubrication defects and crankcase oil dilution with kerosene play havoc with bearings. This was particularly true in the case of the older heavy-type machines, with which the operator who could get through the week without overhauling the bearings was a wonder. This we successfully combated with proper carburetion, hard babbitt (S.A.E. No. 24) and hardened crankshafts. By applying what we learned on the big machines, the small ones became easy. We find a serious condition with the valves in kerosene engines. Cylinder design and the manner of supporting the valve probably cause the majority of our troubles. Valve-seats are not produced with the precision they rightfully deserve; witness valve-seats after they have been given the so-called "perfect seat." Wipe one absolutely clean, burnish it in and note the result. This is not a plea for better valve-seats unless we want to use cheaper valves. An imperfect valve-seat allows hot gases to bring the valve up to oxidizing temperature, and then we have valve trouble. The oxidizing temperature of the valve material is the key to the problem. Let your valve heat above this temperature, even with a perfect seat, and you are lost.

Cast iron would be the prize performer here if we could only fasten it to an alloy stem satisfactorily. Our firm has put out hundreds of large slow-speed jobs with cast iron valve-heads and mild-steel stems and has not known valve trouble, but the small higher speed engine, with high-temperature exhaust coming at such frequent intervals, does not allow the stem to keep the valve cool enough to prevent oxidizing. We are offered a multitude of valve materials that were used in "Oxyrolls" or some other airplane engine and sound attractive to the manufacturer having valve trouble, whereas all that is necessary is to put a thermocouple in the hottest exhaust passage, get the working temperature and then pick the valve material that has the lowest price with the oxidizing temperature above that in the manifold. I do not mean that we should have poor workmanship in a valve-seat or elsewhere. Other items in our engine are practically the same in respect to materials as in the case of good automobile practice.

In transmission construction, let us dispose of the open geared type by saying that if the designer does not care more for his work than to leave it exposed, no thought should be given to his material; it will wear out anyway unless he will buy manganese steel. Where the bearings are not operated on the shaft, I believe that transmission shafts should be constructed of nickel steel, giving the best shock properties possible. This applies to the smaller uptodate tractors now on the market. Where the bearings operate on the shaft, we must necessarily carry the hardness higher than otherwise, and a little chromium in the shafting steel does wonders. But let me warn you to keep the elastic limit high under these bearings or look for trouble. We will have to condemn the bearing manufacturers here, as apparently they cannot give any reliable data; you must work out your own solution. It is better to put a race under the bearing and do it right. It may save you gray hairs and cold dollars.

On enclosed gears, we can follow automobile practice very profitably on the smaller sizes, with their consequent higher speeds. In the larger-size and slower-moving gears, our firm's experience can be recited. Our large reduction-gears, which are about 22 in. in diameter and have a $1\frac{1}{2}$-in. face, were originally designed for 0.35 to 0.45 per cent carbon steel heat-treated but, owing to the thin section and danger of warping, they were not heat-treated in our experimental machines. They showed excessive wear even when operating in an oil-bath. This test also seemed to indicate that we could not depend on the cast steel we could then procure; so, when a rolled-steel gear-blank salesman came along, we welcomed him with open arms. On the arrival of these blanks we found we could heat-treat them without excessive warping; that is, for a 100-r.p.m. gear. This then was our program, but the steel did not seem to harden uniformly, so we found a drop-forger who thought he could produce these blanks in competition with the rolled-steel maker. But the number of our culls which would not harden properly kept mounting higher. We could very seldom quench these gear blanks twice without excessive distortion. About this time we felt we were on the wrong track and set about producing a perfect gear. This we believe we have done with no additional expense in two cases and for less cost in a third. The gears now are in production on our 20-35 tractor. We started with the idea of using a ring-gear shrunk on a spider, which we learned was giving some companies trouble in a certain measure by the rings splitting off the spider at a point corresponding to the unopened end of the split bar from which it was forged. Metallurgically this method is fundamentally wrong for a heat-treated forging, because strains were left in the ring. They were using about a 0.40 per cent carbon steel shrunk on in water, I believe. Our method is to cut

our gear teeth in a very thin ring, of S.A.E. No. 3140 steel which has been given a heat-treatment prior to machining. This ring is machined about 0.016 in. small on the inside, and on the outside of the cast-iron spider we cut teeth or splines about 3/64 in. deep and of about 3/4 in. circular pitch. This is done on a Fellows gear-shaping machine with the cutter ground back to the pitch line, only one cut being necessary. The gear is then quenched in oil from the proper temperature, no attempt being made to hold it accurately to shape. The drawing operation calls for a high draw to get a No. 475 Brinell hardness. When at the drawing temperature used, the gear opens up so that it will easily slip over the spider where, on cooling, it shrinks in place. The satisfactory part of this operation is that no excessive strains in relation to the elastic limit are left in the gear, and yet a very good press-fit has been secured.

As a test for strain, we cut one of the gears through with a rubber disc wheel and, to our surprise, there was no disturbance such as is caused by a bursting band, and the gear did not open up. These gears are on so tight that they can just be moved in a sidewise direction with a heavy babbitt-hammer when the spider is well supported at the rim. To make sure that no side movement occurs, we put about three rivets through the spider with their heads overlapping the ring. It may be well to point out that the saving in this method is that we have reduced the weight of the high priced material enormously and we make the spiders of cast iron in our own foundry. The case that showed the reduced cost was in a bull gear which contained the differential. The differential spider was carried out to form the spider for the ring.

The volume of production makes a great difference in our specifying of steels, as was pointed out in the case of front axles. We find that certain steels are more easily cut in our machine shops. The relative order of production values that are generally conceded the alloys, seems to be chrome vanadium, plain chrome, plain nickel and chrome nickel in increasing order. This explains in some measure why our large-production automobile builders favor chrome vanadium, although it has a further so-called virtue of hardening satisfactorily over a wider range of temperature. We find production influencing our design in heat-treating, as well as in the machine shop. Parts are made for better group handling, as a job where we quench three a day by hand would swamp producers such as Ford, as they could not get or keep enough skilled men for this operation, aside from providing room for them.

HEAT-TREATING

We find in the S.A.E. HANDBOOK specifications for heat-treatments of steels. To me these are vague and decidedly not specific and are good only for an indication of the treatment. The quenching medium cannot be placed in the specification because different sizes require different media and the proper drawing temperature has to be obtained from the designer's or heat-treater's experience. These specifications should not be taken too literally, as has been already pointed out.

In a general way, we find that annealing is used for (*a*) removing strains, as in cast iron cylinder heads; (*b*) softening material, as in old tools to be recut; and (*c*) to obtain a maximum refinement of grain, as in cast steel. We should use annealing before machining on all forgings of mild steel for grain refinement and the elimination of hard spots.

A preliminary heat-treatment should be given all alloy forgings or highly stressed parts or where distortion is objectionable. We all know that the object of quenching after machining is hardening. The subsequent draw may be to accomplish (*a*) toughness or (*b*) the removing of strains. We carburize for a hard surface and heat-treat for a tough core. For example, our knowledge is applied thus:

(1) Gears which carry little stress and little wear need no treatment when made of cast iron, mild steel or bronze
(2) Where we have a large amount of wear and light stresses, we use mild steel, carburized and treated by single or double quenching and then drawn
(3) For extreme wear and high stress we use alloy steel carburized and given a preliminary heat-treatment, double quench and draw
(4) For high stress and low wear, we use the alloy steels with preliminary heat-treatment, single oil quench and draw
(5) For extreme wear and stress, we may have to use a self-hardening alloy steel with even two preliminary heat-treatments and an oil or air quench and draw

We find special operations that accommodate design or production, such as copper-plating a piece on all surfaces to be left uncarburized, or we apply a supplementary operation after the pieces have cooled off in the carburizing boxes and before hardening, such as machining excess stock which carries a case from the carburizing operation. This leaves the material soft on desired surfaces, after the usual quenching or hardening treatment.

One further thing is the heat-treatment of manganese steel castings; all of these are quenched from about 1800 deg. fahr., in water. Before this operation the material is very hard and brittle. The control factor in production work is all-important and is a broad subject; it includes furnaces, temperature indicators and inspection guided by limits set by the engineering department.

THE DISCUSSION

A. H. BATES:—Mr. Moody spoke about a double quench and a draw for gears. We give many of our gears only one quench.

C. S. MOODY:—The object of the double quench and the draw is simply to refine the gear further in the core. If two different kinds of steel are taken, we must quench them at different temperatures to get the maximum refinement in each. When we have a case-hardened gear, we have a surface of high-carbon steel on the outside and on the inside a mild-steel core. With the double quench we use a high temperature, probably 1550 or 1600 deg. fahr. for the first quench, to refine the internal part of the gear or the core. It also hardens the case, but it leaves the grain size in the case fairly coarse; so we give a second treatment. This is a quench from about 1350 to 1400 deg. fahr., possibly a little higher, depending on the steel; that refines the case and at the same time acts as a drawing operation on the core, toughening it. We can demonstrate that very easily if we take a mild-steel rod, carburize it, break it and give one piece a single quench and another a double quench, using the proper temperatures. One cannot bend the single-quenched rod, but can bend the second and fracture the case without having the fracture progress through the core.

MR. BATES:—Is there not then more warpage? We had an instance in which we wished to change some hardened gears; in going over them again, drawing and quenching, we found there was considerable warpage.

MR. MOODY:—There is a tendency toward that. I do not know what your methods of fitting were. My opin-

ion is that no gears can be put into a tractor without being fitted; that is, machining the surfaces or grinding to fit the shaft. In other words, I prefer to have the machined surfaces finished after heat-treatment. If that is done, much more distortion can be allowed. For instance, with a light thin gear one is apt to get into difficulty with distortion; care must then be taken to eliminate it.

E. F. NORELIUS:—Has Mr. Moody had experience in the case-hardening of crankshafts?

MR. MOODY:—The case-hardening of crankshafts is new. I doubt very much if it really warrants the extra trouble it causes. It can be done. From what I have read I judge that the process can be simplified very much, getting the wearing surface where we want it. A considerable amount of work is necessary in this connection and the equipment must be much more extensive.

R. S. KINKEAD:—In a single treatment such as Mr. Bates referred to, the air is kept away from the part prior to and during quenching and, as a rule, the part comes out clean; but in reheating for a second quench the gas or air that comes into contact with the part oxidizes it and forms a scale that is wholly objectionable. We tried to overcome that objection in some of the smaller parts we have been making.

MR. MOODY:—I cannot say too much against the practice of quenching from the carburizing boxes; as the pieces are hot, the carburizing temperatures being about 1700 deg. fahr., an excessively large grain-size is produced and a brittle product is the result. If the pieces are large and can be quenched that way easily, it is all right and it is cheaper. Regarding the scale that occurs, as a matter of fact, our gears are cooled off in the boxes and reheated twice from the cooled state. That is to get the benefit of going through the critical range, refining the core, coming back up again and recrystallizing the case. The scale referred to is almost entirely under the control of the furnace operator. He generally uses three times as much air as is necessary. After about three years of effort I have trained my furnace operators to look for a "lazy" heat. We are not getting complete combustion because we have not enough oxygen. When we have an insufficient amount of oxygen we cannot get scale. Our operations provide for cleaning after the complete treatment is finished. We use a sand-blast with shot, and we can use the shot again and again.

MR. VALENTINE:—For a front axle on a 1000-lb. machine, would you use cast steel or a good malleable iron?

MR. MOODY:—I think it would not make much difference. I favor cast steel, particularly if a fairly good-sized production is expected. We get good results from malleable cast iron, but just as soon as we get on a production basis we have to examine all the axles for hardness.

L. F. NIELSEN:—Is there not some way other than the use of a sand-blast to eliminate the scale? What of the sulphuric-acid pickle?

MR. MOODY:—The sulphuric-acid pickle endangers the workmen; the acid also works into the steel. Research has proved that it leaves the steel more brittle than the other methods of cleaning. The process is dirty and messy and the acid must be washed off the parts with hot water. I think the process will be found to be much more expensive as well.

MR. NORELIUS:—As to the treating of hardened cast-steel, we have made a practice of subjecting drag-links, having approximately 0.35 per cent of carbon, to an oil-quenching treatment. What would Mr. Moody recommend?

MR. MOODY:—I have had to do many things with cast steel. We are water-quenching one particular gear coupling, followed by a low draw. I believe that anything can be done with cast steel that can be done with forged steel, within the limits I have mentioned. We generally give a double treatment; first, a quench from about 1600 deg. fahr. to break down the grain-size; second, a regular treatment, such as we would give forged steel. But there appears to be little call for heat-treated cast steel, aside from the tractor line. Tractor men seem to be the only ones who are doing any new work on cast steel.

MR. NORELIUS:—Do you quench in water and draw?

MR. MOODY:—Yes. Oil is all right, however; it all depends on what is desired. Sometimes we quench in oil because we do not want the product as hard as we get it with water, with the added danger of distortion.

MR. NIELSEN:—To what degree of hardness is it safe to draw cast-steel axles; for instance, the ordinary casting containing say 0.30 per cent carbon?

MR. MOODY:—Do you refer to a quenched or an air-cooled axle?

MR. NIELSEN:—A quenched axle.

MR. MOODY:—I do not know whether you desire strength or hardness but, ordinarily, in a cast-steel axle strength and considerable toughness are desired. We formerly used a temperature of about 1550 deg. fahr. and cooled in air; then we would draw at 1100 deg. fahr. and cool in air. A good example of what that will do is our experience with axles at about the time we became interested in smaller size tractors. We wanted a drop-forged axle but could not get it; we were forced to take cast steel and we performed the operation I have mentioned on the axle. But we had to have the steering-arm on the same machine also of cast steel. We were not concerned about that; so nothing was done with it. I have a distinct recollection of one of our 16-30 machines coming back after a railroad accident in which the car had been badly jammed. We found the wheel on the left-hand side was lying absolutely flat; in other words, the axle had been bent more than 90 deg. but the steering-arm on the end of that axle had been snapped right off straight. As to the hardness, that all depends on what strength is desired; only a certain strength can be attained at a given hardness. In any event hardness is variable when using cast steel, because it does not run so uniformly as a good forged steel. I do not know what your conditions are. I imagine a Brinell hardness of about 200 would give fair stiffness. That is about as far as one would dare to go with say 4.2-in. diameter. You might draw down as low as 650 deg. fahr. I think I would go no lower than that.

A MEMBER:—Do you use 0.30 per cent carbon steel or higher?

MR. MOODY:—We use steel having about 0.35 to 0.45 per cent of carbon. When it is quenched and drawn it goes to a 90,000-lb. maximum elastic limit. We have done something with that on some of our steering-arms, where we could not get a drop-forging, on our 20-35 machine, for instance, and have not had any trouble.

H. E. JOHNSON:—Has Mr. Moody had experience in testing various steels at different intervals? I have in mind the testing of steel balls. After a ball has gone through its heat-treating process, it is tested shortly subsequent to being finished. In testing ⅝-in. steel balls the second or third day after they were considered finished, we could not get a greater crushing strength than approximately 12,000 lb. Two weeks later the same balls were tested again and we found that the crushing strength was as high as 28,000 lb.

MR. MOODY:—After work has been done on any piece of steel, a variation will be found between the time directly after the work was performed, and some time after that. When we were doing shell work, the only way certain companies could get their shells right was to let them lie on the radiator for a time and obtain the elongation in that way; they could not do it immediately after machining. There is some stress in the metal and the strains are equalizing themselves. If there are strains due to quenching or machining or anything like that, a part of the elastic limit is being absorbed. Any stresses applied after that can only make up the difference between what one has already used and the elastic limit. In the case of your example I would question the method of testing before I worried very much about a large variation like that.

MR. JOHNSON:—That range seemed very evident in exhaustive tests. We tested thousands of balls in that same manner.

MR. MOODY: — What heat-treatment are you giving them?

MR. JOHNSON:—One operation is that of quenching in boiling water, which seems to give far better results.

MR. MOODY:—Do they do any drawing back on that?

MR. JOHNSON:—I think they do.

MR. MOODY:—Unless they did this, there would be apt to be strains in the balls. It would take some time to neutralize such strains by aging in air.

IS LUBRICATION A CHEMICAL PHENOMENON?

THE common popular view regarding the action of a lubricant is based on the belief that friction is produced by the roughness of the contacting surfaces. The lubricant, it is supposed, fills up the roughness, and in the layer of it between the surfaces provides a series of molecular balls that acts after the manner of a ball bearing. This theory may be crude and readily open to scientific refutation, but so long as we do not push it too far it is fairly satisfactory. Further, if we associate the conception of the ball-bearing action of the molecules of the lubricant with the property of fluids that we call their viscosity, the theory reflects the importance that, in practice, is attached to the viscosity of lubricating bodies. This hypothesis is, at best, only tenable when we assume that we are dealing with fully lubricated bearings; that is to say, bearings in which the two surfaces are definitely floated apart on a film of lubricant of material thickness. In such a condition the fluid substitutes its own internal friction, or viscosity, for that of the one clean metal on the other, but between the viscous friction of completely lubricated surfaces and the dry friction of completely unlubricated surfaces there is an intermediate condition described, perhaps a little unfortunately, as the greasy friction of partially lubricated surfaces.

Crudely speaking, we may say that in partially lubricated bearings there is no interposing film of fluid between the surfaces, that the surfaces are in contact, and that the lubricant is present, at most, only to the extent required to fill up the roughness. This oily condition can be produced by wetting a clean surface with lubricant and then wiping it. Lord Rayleigh, it may be remarked, studied the greasy state by glass plates smeared with the fingers after they had touched the hair. It is not, we think, a matter for surprise that the laws of viscous, greasy and dry friction should be found to be radically different. In dry friction the coefficient varies with the material of the contacting surfaces and their state of preparation. In the case of viscous friction the coefficient is hardly affected by the nature and condition of the surfaces, but varies primarily with the lubricant used. Turning to greasy friction, we find that the coefficient, according to R. M. Deeley's experimental results, varies both with the nature of the surfaces and with the lubricant used. The significance of this statement can be illustrated by a specific example. As a means of reducing friction between mild steel and cast iron, olive oil and rape oil tied for first place out of 11 different oils tested, while castor oil and Manchester spindle-oil tied for fourth place. But when the oils were tested between mild steel and gun-metal the order of merit was very different. Rape oil again occupied first place, but olive oil fell to the fifth. Castor oil moved up to the third position, but Manchester spindle-oil fell to the ninth. The lubricating value of an oil in a partially lubricated bearing, if these results can be accepted, does not, therefore, depend solely on the oil, but is largely determined by the precise metals of which the surfaces in contact are composed. From these observations Mr. Deeley has been led to the belief that the oil film in partially lubricated bearings is not oil per se, but is actually a compound formed by the oil with the metal. The compound is in his opinion not a mere mixture or interlacing of the molecules but a definite union attributable to the action of interatomic forces. In other words, it completely and exactly fulfills our conception of a chemical compound, and in our opinion can, in the case of a fatty lubricating oil, be conveniently referred to for the purpose of discussion as oleate of iron, copper, cupro-tin, etc. In this connection it is to be noted that common soap is formed by the union of fatty acids with sodium or potassium. The alkali can, however, be replaced by various other metals. Thus "soaps" formed by the union of fatty acids with iron, nickel, cobalt, zinc, magnesium, aluminum, copper or mercury are possible, and are actually made and used for a wide range of industrial purposes. The suggested union of the oily molecules with the molecules of the contacting surfaces in a partially lubricated bearing is thus not a chemical absurdity so long as we confine ourselves to animal or vegetable oils. In the case of mineral lubricating oils, however, the nature of the suggested compound is less readily pictured, although it is possible, by Mr. Deeley's theory, to propound an explanation of the facts reported by Messrs. Wells and Southcombe in support of their "germ" theory regarding the addition of small quantities of free fatty acid to mineral lubricating oils.

It may be true, as stated in the report of the Lubricants Inquiry Committee, that "at the present time only a comparatively small number of bearings and rubbing surfaces are working under conditions of complete lubrication, and that an immense majority are working either wholly or in part as partially lubricated surfaces." Still, the fact remains that the partially lubricated bearing is hardly more efficient than a dry bearing and should be avoided in practice. The exact laws governing partial lubrication can, therefore, have little direct practical application. At the same time we recognize that if chemical action is at the basis of partial lubrication it must also enter in some degree into complete lubrication, and that such a revolutionary belief could not be established without affecting our whole outlook on all the problems of lubrication.—*The Engineer* (London).

Important Factors in Piston-Ring Design

By H. H. Platt[1]

Washington Section Paper *Illustrated with* Diagram

THE purpose of piston-rings in an internal-combustion engine is to reduce to a minimum the leakage of gas from and the seepage of oil into the combustion-chamber. Asserting that the widely held idea that the leakage of gas past the piston can be eliminated by the use of good piston-rings is incorrect, the author states three possible paths for such gas-leakage and, after commenting upon them, discusses diagonal and lap joints and the subject of leakage with special reference to them.

After considering the design of rings for gas-tightness, the author shows a fortunate mathematical relationship, in connection with the application of uniform radial pressures, regarding the bending-moment stresses. Oil leakage is treated in a similar manner and the conclusion is reached that the properties of the material used are of extreme importance.

THE purpose of piston-rings in an internal-combustion engine is to reduce to a minimum the leakage of gas from and the seepage of oil into the combustion-chamber. There seems to be a widely held notion that the leakage of gas past the piston can be eliminated entirely by the use of good piston-rings. That this is not the case can be demonstrated by removing the crankcase cover from a warm engine and noting the bubbling and hissing of the escaping gas when the engine is turned over slowly; the exact volume of gas leaking past the pistons of an operating engine can be measured better by closing all openings from the crankcase except one, which is connected by a pipe to a calibrated gas-collector. Precautions must be taken to maintain the pressure and temperature of the collected gas at as nearly atmospheric conditions as possible. Knowing the piston displacement, we can easily write the leakage as an approximate percentage of the air passing into the engine at full load. Extremely good values for the leakage at full load are 2 per cent at 400 r.p.m. and 0.5 per cent at 1600 r.p.m. With poorly designed piston-rings these values are many times greater. Evidently, then, the loss of power due to piston leakage is never negligible, although it can be reduced to a value that is small in comparison with other sources of power loss.

There are three possible paths for the leakage of gas past a piston-ring. Putting the least important first, these are (*a*) through the gap, (*b*) around the back of the ring and (*c*) past the face. It has long been known that the gain in power resulting from attempts to seal the joint has been insignificant, and that in many cases there has been an actual loss. The reasons for this failure in practice have apparently never been clearly set forth.

The rate of leakage through an aperture is approximately proportional to the area. The smallest sections of the path through the gap are those at the entrance to and the exit from the gap. The section at each of these points is a nearly rectangular orifice bounded by the cylinder wall, the piston surface and the ends of the ring. The maximum area of this opening is the piston clearance multiplied by the clearance between the ends of the ring. Under operating conditions, for a medium-sized cylinder, these values should not exceed 0.004 and 0.005 in. respectively. The area of the aperture is then $0.004 \times 0.005 = 0.00002$ sq. in.

Suppose that for a portion of its circumference the ring fails to make full contact with the cylinder-wall or with the side of the groove in the piston. Then the area of the crack exposed to leakage is equal to the product of its length and its average width. A very slight inaccuracy would give rise to an opening having a length of 1 in. and an average width of 0.0002 in. The area of such an opening is 0.0002 sq. in. and, if we assume an aperture of this size for each leakage path, the total area is 0.0004 sq. in. or 20 times the gap area calculated above. It is plain, therefore, that the advantage of stopping the joint leakage cannot be expected to balance the inaccuracy introduced by the complicated construction necessary to accomplish that end. This conclusion can be confirmed by observing the distribution of the bubbles of escaping gas around a piston equipped with plain-jointed rings. No preponderance in the neighborhood of the gap will be noticeable. Thus we are brought to the necessity of deciding between the two simple types of joint, the diagonal and the lap.

Diagonal and Lap Joints

The only possible advantage of the lap joint is reduction of gap leakage. The idea that it has any appreciable effect in this direction is utterly fallacious. The gas leaking through the small orifice at the entrance to the gap passes directly into the comparatively large space in the groove back of the ring, which connects directly with a small orifice at the exit from the gap. The leakage path past a lap joint consists, therefore, of three portions; these are a restricted entrance, a large central passage and a restricted exit. The same thing is true of the path through a diagonal joint, and the area of the restricted orifice, which is the only area that counts, is the same for each case.

The diagonal joint, on the other hand, has four definite advantages. First, the points are free from the danger of breaking off, which is noticeable in the lap joint. Second, a dull cutter leaves a fillet in the corner of the lap joint. The opposite sharp point rides on this fillet, thus reducing the effective clearance in the gap and, in extreme cases, causing cylinder scoring. The diagonal joint is not subject to this trouble. Third, the gas impinging on the diagonal face of the end of the ring has a definite slight tendency to cause the ring to creep around in the cylinder, thus insuring even seating both on the cylinder and in the groove. Moreover, if the diagonal cuts are made and installed alternately right and left

[1]Chief engineer, Wilkening Mfg. Co., Philadelphia.

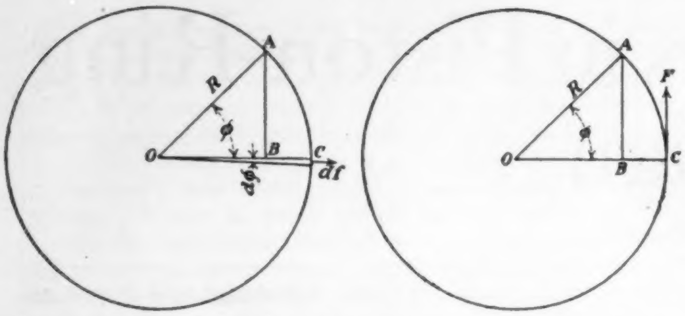


FIG. 1—DIAGRAM SHOWING THE RELATION OF THE FORCES ACTING UPON A SPLIT PISTON-RING

handed, the creeping is in opposite directions for alternate rings and all the gaps cannot stay in line. Fourth, and probably most important, the simplicity of setting and holding for the plain diagonal cut insures greater accuracy. In reducing the leakage around the back of the ring, accuracy in machining both the ring and the groove is of paramount importance. Other desiderata are freedom from warping and maximum width of contact between the ring and the groove.

It is usually supposed that no leakage can occur past the face of a ring that has a complete circumferential bearing. A little consideration will show that this supposition is incorrect. Between the ring and the cylinder surface there exists a film of oil which prevents actual metal-to-metal contact. The thickness of this oil-film depends upon the body of the lubricant, the smoothness of the surfaces and the pressure per unit area. The oil is held in place only by capillarity and viscosity. The sum of these retaining forces in the case of the lubricants and surface pressures available in practice is never equal to the displacing force of the high pressure in the combustion-chamber. Consequently, some of the oil is blown out of the film space and some gas follows it. This conclusion has been verified by leakage tests in which rings of varying pressure, otherwise exactly similar, were compared. Leakage invariably increased with a reduction in the surface pressure. These results would point to an advantage in giving the pressure a maximum value. Increasing the pressure, however, increases the friction loss correspondingly and a point is soon reached where the gain is entirely offset. The pressure that produces a combined minimum power-loss varies greatly for different designs of engine and for different classes of work. When a very high surface pressure is desired, it can be obtained by relieving a portion of the face of the ring with oil-grooves and the like. This practice is not generally recommended, however, on account of the more rapid wear of the ring and the cylinder.

DESIGNING RINGS FOR GAS-TIGHTNESS

If a ring presses against the cylinder-wall with the same pressure at every point of its circumference, the oil-film will be of uniform thickness. If, however, there is a variation in the pressure at different points, the oil-film and the leakage space will be greater at some points than at others. It is evident, therefore, that the total leakage past the face of a ring is considerably increased by uneven surface pressure. The actual saving resulting from careful attention to this point is even greater than one would suppose possible. In an impartial test rings made by a process that produces approximately uniform pressure were compared with several other makes less accurate in this respect. All rings were made to the same specifications and all were light-tight in a standard gage. The uniform-pressure ring allowed the passage of one-third less gas than did its closest competitor.

The most important factor in designing for gas-tightness is, therefore, the development of a process for imparting to a ring the property of exerting uniform radial pressure against a round cylinder. It is easy to show by a simple analogy that, to meet this requirement, the ring must have a very definite shape. If we apply uniform downward loading to a straight cantilever beam it will deflect in the form of a parabola. If the beam were set in the parabolic form and the loading removed, it could be brought back into straight-line form only by the application of uniform upward loading equal in value to the original downward pressure; that is, if a flat horizontal surface were pressed upward against the beam, the pressure against that surface would be uniform throughout the length of the beam. The two halves of a piston-ring can be considered as cantilever beams fixed at the point opposite the split. Evidently, then, if we expand a split tensionless ring by the application of uniform outward radial forces, each half takes on a definite shape which bears a relation to a semicircle similar to that of the parabola to a straight line. If the ring is set in this shape and the load removed, it is evident that it can be compressed into its original circular form only by the application of forces exactly equal and opposite to those by which it was originally expanded; that is, by uniform radial inward forces. Therefore, when placed in a true cylinder of correct diameter, the forces acting between the ring and the cylinder must be uniform around the entire circumference.

The application of uniform radial pressures would present serious practical difficulties if it were not for a very fortunate mathematical relationship. At the left of Fig. 1 a split ring is shown, of radius R, with the split at the point C. Assuming that the ring is acted on by uniform radial expanding forces whose intensity is f weight units per unit length of arc, and that $\partial\phi$ is an indefinitely small angle, then

$$\partial f = fR\,\partial\phi$$

where ∂f is the radial force acting on the arc subtended by the angle $\partial\phi$.

If the bending-moment at any point A, removed from C by the angle ϕ due to the force ∂f is ∂m.

$$\partial m = \partial f \times AB$$

where AB is the perpendicular distance between A and the line of the force ∂f.

But

$$AB = R \sin\phi$$

Substituting,

$$\partial m = fR^2 \sin\phi\,\partial\phi$$

The total bending-moment at A equals the summation of the moments resulting from all the forces between C and A. Using M to represent the total moment at A,

$$M = \int_0^\phi \partial m = \int_0^\phi fR^2 \sin\phi\,\partial\phi$$

Integrating and simplifying,

$$M = fR^2(1 - \cos\phi)$$

At the right of Fig. 1 the same ring is shown, but it is acted on at C by a tangential force F. The bending-moment M, at the point A is written

$$M_1 = F \times BC$$

where BC is the perpendicular distance between A and the line of F.

$$BC = R - OB$$

and

$$OB = R\cos\phi$$

Therefore

$$M_1 = FR(1 - \cos\phi)$$

Comparing this equation with the formula for M, we see that $M = M_1$ when $F = fR$.

The bending-moment stresses produced by uniform radial expanding forces are, therefore, identical at every point with those caused by tangential forces of the proper value applied at the split. Since the curvature at every point depends only on the bending-moment stresses, tangential forces applied at the split produce an expanded ring having exactly the same shape as that resulting from uniform radial forces. Therefore, to produce a ring of the correct form we need merely pull the joint apart, insert a spacing piece and subject the expanded ring to a sufficiently high temperature to release all internal stresses. It should be noted that the mathematical relation is independent of the shape of the section and of the actual values of the stresses at any point. Consequently, variations in thickness and in quality of material have no effect on the property of radial uniformity of pressure.

The practical application of this method introduces minor difficulties and inaccuracies that need not be set forth in detail here. The difficulties have been overcome successfully and the inaccuracies, very small in the first place, fortunately happen to counteract each other; so, even in quantity production, the rings show astonishingly small variation from the correct shape. These rings are accurately ground before splitting and are not refinished after the shaping process. Therefore, they possess a distinctive blue-black coating of iron oxide. The finished rings are tested for accuracy by the light test, and practically 100 per cent pass it; also by the ring-gage test which has been modified to make it easier of application. The ring is forced into the proper ring-gage, the ends are clamped together and it is then withdrawn. Evidently when freed, the points at which the pressure against the gage is greatest spring outward, causing the ring to assume a slightly non-circular shape. The deviation from circularity, measured with micrometer calipers, is an indication of the uniformity of the radial pressure. The majority of the rings are so nearly round that the deviation is not measurable. The greatest difference between the maximum and minimum diameters is not allowed to exceed 0.005 in. Other makes of ring usually show at least three times this discrepancy.

Oil Leakage

The chief requirements for preventing excessive oil-leakage are the same as those for gas tightness. In addition, it is of great importance to reduce to the minimum the volume of the space in the groove not occupied by ring material. Any such space acts as a first-class oil-pump and tends to fill with oil at the bottom of the stroke, where the conditions are those of suction and abundance of oil, and to empty at the top of the stroke when the oil is driven from the space by high-pressure gas. This fact eliminates the eccentric ring from serious competition and makes it important that the concentric ring should fill the groove as completely as safety permits.

Two important relations can be derived from the foregoing mathematics. It can be shown easily that

$$p = F \div wR$$

where

F = tangential force applied at the gap necessary to compress the ring to the cylinder size
p = pressure per unit area
R = radius
w = width of face

This tangential force is approximately one-half the more easily measured force which, when applied normally at a point 90 deg. from the gap, closes the ring to the cylinder diameter. The most satisfactory general-purpose pressure is thus found to be between 8 and 10 lb. per sq. in.

The second relation is an equation for ascertaining the maximum working unit-stress on the material of the ring. Applying the ordinary beam formula we find that

$$S = 12FR/wt^2$$

where

S = maximum unit-stress
t = thickness of the ring at the point opposite the split

Written in terms of surface pressure this equation becomes

$$S = 12p(R/t)^2$$

This formula gives, for a ring of suitable dimensions having a surface pressure of 10 lb. per sq. in., a maximum stress of about 30,000 lb. per sq. in., which is undoubtedly somewhat above the actual value because of the deviation of cast iron from the condition of perfect elasticity upon which the beam formula is based. Nevertheless it serves to show that the working stresses in piston-rings are very close to the safe limit and much greater than those used in any other cast-iron part. The failure of many piston-rings is certainly due to the use of excessive stresses.

In determining the most suitable gap-opening we must consider the stress produced by forcing the ring over the piston. Obviously, breakage or serious distortion will result if this stress exceeds a safe value. On the other hand, the use of a wide gap to reduce this danger increases the working stress. The best opening is, therefore, one that nearly equalizes the two types of stress; that is, a gap that measures circumferentially about four times the thickness of a concentric ring.

These considerations make it evident that the properties of the material used are of extreme importance. If the iron is soft, of open grain and has a low modulus of elasticity, the requisite pressure cannot be obtained without excessive working stress. On the other hand, if the iron is very hard, close grained and possesses a high modulus of elasticity, a gap large enough to allow safe springing over the piston gives rise to too high surface pressure and working stress. Moreover, if the ring material is much harder than that of the cylinder, excessive wear results. The degree of hardness in iron castings increases with the rapidity of cooling; therefore, the smaller the section of the casting, the harder the material should be. We have found that small individual castings have too small a section for the best results, while long-pot castings are entirely too soft. We have, therefore, developed a short-pot method in which castings about 2 in. long are used. The properties obtained in this way afford a very satisfactory compromise between the two extremes.

THE DISCUSSION

F. DAVIS:—I understand that the ring is heated to a certain temperature when expanded. What is that temperature?

H. H. PLATT:—We have found 1200 deg. fahr. a satisfactory temperature, but a considerable range could be used.

MR. DAVIS:—Does not the structure of cast iron change at 1200 to 1250 deg. fahr.?

MR. PLATT:—We find no appreciable change due to heating cast iron to 1200 deg. fahr. At temperatures considerably higher changes do occur.

MR. DAVIS:—Is there not a tendency to form temper carbon which affects lubrication?

MR. PLATT:—We have found no such effect. At temperatures somewhat higher than those we use we have found an actual increase in graphitic carbon, which would indicate improved lubricating qualities. Commercial chemical analyses, however, are not able to detect any difference between our treated and untreated materials.

MR. DAVIS:—Does not a piston-ring so treated tend to lose its tension when subjected to heat in the cylinder?

MR. PLATT:—A leakage test was conducted by the Cadillac Motor Car Co., under identical conditions, of five types of ring at various speeds, all at full load. The results are summarized in the form of performance percentages, the performance of a ring listed as a Cadillac being arbitrarily assumed as 100. These figures are as follows:

LEAKAGE TEST OF PISTON-RINGS

Ring	Percentage
Standard	100.0
Pedrick (heat-treated)	133.0
No. 3131	105.0
No. 2830	45.4
No. 2829	67.8

Also, actual leakage in cubic feet per hour is given for various speeds from 800 to 2000 r.p.m. Here we find the respective leakages at 800 r.p.m. for the heat-treated Pedrick ring and ring No. 3131 to be 58 and 56; they are almost identical. At higher speeds, however, we find ring No. 3131 falling off in comparison until, at 2000 r.p.m., the figures are 55.7 and 96.0 respectively. The heat-treated ring is the only one in the entire list that shows less leakage at 2000 than at 800 r.p.m. This is certainly strong evidence against any theory to the effect that these rings lose tension under severe service. Ring No. 3131 is described as a lap-joint, peened concentric ring; the make is not stated.

Another test referred to is one described in a paper[2] by A. L. Nelson entitled Fuel Problem in Relation to Engineering Viewpoint. In this test the engine was run under very severe conditions a number of times without any let-down in performance. Heat-treated Pedrick rings were used in this test. We have had no complaints about loss of tension; indeed, we have been told by garage-men of rings that have run for more than 100,000 miles and are still retaining the complete original tension.

MR. DAVIS:—Has any difficulty been experienced in the use of such rings in motorcycle engines, where the service is more severe than in the average automobile engine?

MR. PLATT:—We have had no trouble with such use. One of our oldest users is a motorcycle manufacturer.

MR. DAVIS:—Has any test been made to determine the evenness of wear of rings so made?

MR. PLATT:—We have tried rubbing rings up and down in a cylinder. The wear appeared to be even.

MR. DAVIS:—Would not a light-tight ring also do this?

MR. PLATT:—If the pressure were uneven, a difference in the bearing would be noted at different points.

H. S. MCDEWELL:—Have you made any device for measuring radial pressure accurately?

MR. PLATT:—No device of this kind that I have seen is capable of differentiating between inequalities of pressure due to inaccuracies in machining, which soon wear off, and inequalities due to incorrect shape, which are permanent.

MR. MCDEWELL:—What do you estimate that a deviation from roundness of 0.005 in. means in actual figures of pounds per square inch in the test that you described?

MR. PLATT:—I have made no attempt to determine the actual values. Our tests have been comparative only.

C. W. TUCKER:—Should rings be closed? What do you allow for the sawcut when grinding oversize?

MR. PLATT:—We use a 1/32-in. saw and allow about 0.010 in. oversize to close the sawcut to the proper end-clearance.

MR. TUCKER:—What is a reasonable end-clearance for a ring? Would there be danger of scoring if it were kept down to 0.002 in.?

MR. PLATT:—A reasonable end-clearance for a medium-sized automobile engine is 0.005 in. There would be danger of scoring if 0.002-in. end-clearance were used. We find great difference of opinion on this point, however.

MR. MCDEWELL:—Do you find that heat-treated rings require less clearance than other rings?

MR. PLATT:—We have found no difference.

MR. TUCKER:—Is there any rule for the clearance between a ring and the bottom of the groove?

MR. PLATT:—That depends upon conditions, such as the size of the ring and the cylinder. We have found 0.01 in. to be a good general rule.

A. W. MORTON:—Do you find it necessary to return or regrind the rings after cutting them?

MR. PLATT:—No. An interesting point is that we tried both methods and found that the refinished rings were actually less accurate than those finished before splitting.

MR. DAVIS:—A section of a ring 2 in. long has a certain form when ground oversize. Does this shape change when a spacer is inserted at the ends and the ring is subjected to heat-treatment?

MR. PLATT:—The original ring is circular. No part of the finished ring is circular.

MR. MORTON:—Is one tension advisable for all sizes of rings?

MR. PLATT:—In our standard rings we use the same working stress for all sizes and the same surface pressure. In making rings for manufacturers who furnish their own specifications, we meet those specifications without question on the assumption that the manufacturer is better fitted to prescribe for his special condition than we are.

W. M. WALLACE:—In the May, 1921, issue of THE JOURNAL there is printed a short discussion[3] I made of A. L. Nelson's paper in which attention is drawn to certain major features of design that seemed to have been overlooked by engine designers generally. The matter of fuel economy in the millions of existing engines, coupled with the poor grade of fuel at present obtainable, indicates the importance of the greatest possible effort by all interested to solve the perplexing question in a practical and unselfish manner. If we must change our ideas completely, it should be done as promptly as the soundness of the premise is established.

I have followed the trend of piston design in a general way for many years, because it seemed to me that the ultimate success of the design would be measured in this one part almost wholly. I regard the piston as the most important single part of any engine. It receives at first hand all of the work that comes from the combustion-chamber. Its success or failure is measured in thousandths of an inch. Failure to be tight and keep tight invites loss of fuel with all its attendant difficulties. It is difficult to lubricate properly and over-lubrication is a constant source of vexation and expense. The piston is a

[2] See THE JOURNAL, February, 1921, p. 101.

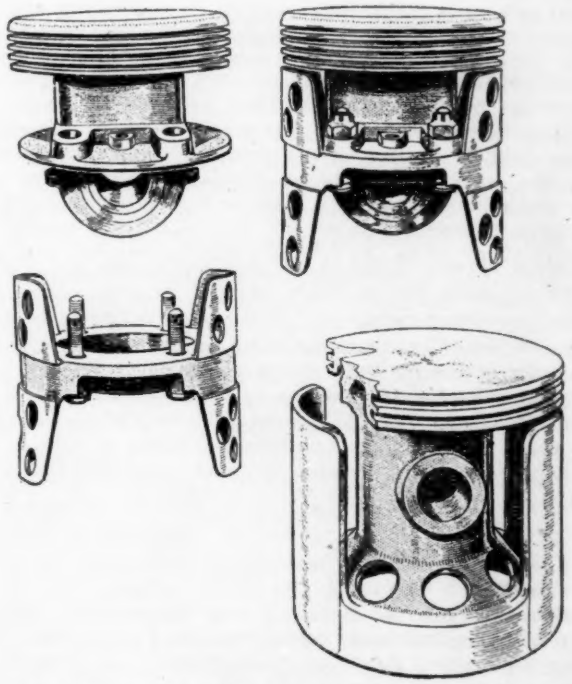
[3] See THE JOURNAL, May, 1921, p. 458.

possible source of great friction. A piston can be made tight when new with almost any kind of ring, the piston itself embodying almost any kind of novelty in design to suit the fancy of the designer. Pistons can be made of various materials and of various shapes. In the beginning, when the materials distort after they become hot, we can apply corrective measures, but to keep pistons tight they must be proof against undue wear and subject to adequate lubrication. This requires the use of proper material for the purpose, and design such that the bearing pressures will be uniform, thereby permitting efficient lubrication, reducing wear and keeping the crankcase clear of its great enemy, free gasoline.

Some take the view that the millions of engines now in use cannot cope with present gasoline conditions. This view is wrong from all angles. Hardly an engine is in existence to-day with a poorly designed piston that is not capable of further good service if provided with a new and specially designed piston that is interchangeable with the old one. Each engine presents problems of its own, but slight research in each case, intelligently applied, will solve the problem to the extent of showing great improvement. Having provided good substitutes for poorly designed pistons, let them be put at once into production, inclusive of parts stock. In this way, in an astonishingly short time, not only will the reputations of the makers be enhanced, but good service will be reported from older models that have been rehabilitated.

Developments in Piston Design

IN addition to their efforts to raise combustion and carburetion efficiency, it is evident that British automotive engineers have given no little thought to the matter of mechanical losses. In their analysis of engine performance several of the authorities have concluded that steps can be taken to increase the mechanical efficiency of high-speed internal-combustion engines by certain design modifications. In a report on airplane engine efficiencies Dr. A. H. Gibson presents data that show the effect of piston friction on brake mean effective pressure and emphasize the importance of this loss when an increase in overall engine efficiency is attempted. Harry Ricardo also has worked on the solution of the problem of reducing piston friction and evolved the interesting design shown at the left of the accompanying illustration. In this piston aluminum is employed as the material for the head in view of its high heat conductivity and light weight. The skirt or slipper is made of cast iron which in addition to its proved value as a skirt material has the advantage of a lesser coefficient of expansion and can be fitted to the cylinder with a minimum clearance. The lack of a direct path for heat travel to the skirt and the fact that most of the heat is conducted through the rings to the cylinder-walls should still further reduce any chance of seizing. The elimination of all slipper surface that is not of direct value in carrying the piston side-pressure should reduce friction to a minimum and decrease the work lost in shearing a large oil-film. Judging from the illustration, the design is also attractive from the production engineer's viewpoint.



TWO PISTONS THAT HAVE BEEN DEVELOPED IN ENGLAND RECENTLY
The Single-Piece Piston in the Lower Right Corner Was Produced by Vauxhall Motors, and the Two-Piece Piston That Is Shown Assembled in the Upper Right Corner and Separated into Its Component Parts at the Left Was Designed by Ricardo

Another design equally interesting was evolved by C. E. King of the Vauxhall Motors, Ltd., and is shown in the view at the right. In this type the piston is a single unit cast of one material. Frictional losses are minimized as in the Ricardo design by eliminating all skirt surface not directly useful for thrust purposes. The cantilever construction of the slipper faces no doubt allows considerable flexure and consequent reduction of side-play. It is the designer's theory that the interior cylindrical trunk and the perforated conical flange will transfer to the lubricating oil the greater portion of the heat not lost through the rings to the jacket water and in his way minimize the expansion and contraction of that part of the piston which fits the cylinder bore. This should reduce chance of piston slap and the required clearance of the piston in the cylinder.

The Future of Road-Transport[1]

By Lord Montagu of Beaulieu

A BRIEF review of road-transport conditions in the last 100 years shows how the roads went out of use on the advent of the railroad, and how they have come into use again with the development of the motor car. To-day mechanical road-transport has to face three important problems: (*a*) how the permanent way is to be made and paid for; (*b*) how the fuel is to be secured at reasonable prices, and, (*c*) how commercial road traffic is to be controlled and organized.

While due credit must be given for the work done to the roads in the last 10 years, it cannot be said that even the first-class roads of Great Britain are adequate for present traffic, and it is certain that in a few years they will be totally inadequate for the traffic they will have to carry. As to the second-class roads, they are as a whole unfit to bear much mechanical traffic. The present system of roadmaking is still comparatively temporary in its nature, and annual upkeep is therefore expensive from a rating and taxing point of view. In fact roadmakers are as yet only tinkering at the problem. They have inherited an obsolete system of making roads designed for one kind of usage and now used in a different fashion. They are attempting to live largely on the practice of the past and "to make the clothes of the child fit the man." It is difficult and expensive to make the tracks of the past, originally designed for slow horse-traffic at 8 to 10 m.p.h. with their bad engineering and dangerous corners, suitable for the high-speed mechanical traffic of today or of the future. Again, they are trying to make roads with a surface to suit all kinds of traffic. What is the result? Horse owners justly complain that their animals cannot stand up on asphalt surfaces on a frosty morning, the owner of the pneumatic tire car grouses legitimately at the sharp granite flints or unrolled metal that cuts his tires, and the roadside dweller, market gardener, and the user of the small class of horsed vehicles declare that the main roads have become unattractive owing to the heavy, fast, long-distance traffic, while cottagers complain that their children cannot safely play at the roadside.

Trunk roads, for the new traffic only, must be made between various busy centers, such as London, Birmingham and Manchester. It is unwise, unscientific and uneconomical to try to make the eminently unsuitable become the suitable. Special roads must be made all over the country, and on these mechanical transport should run free from speed limits. If the present speed limits are to be enforced, in a few years the police force will have to be doubled and trebled only for the purpose of keeping heavy traffic down to the speed of the governess cart and the passenger traffic to the speed of a good man-propelled bicycle. The roads, within reason, must be made to fit the traffic, and not the traffic the roads. While, of course, there must be regulations, especially governing speed and weight, the provision of bypass roads avoiding towns will dispense with the reason underlying the wise and inevitable limit in narrow streets. Bypass roads will save time and avoid danger. Many fundamental laws underlying railroad traffic can be applied as they stand to road traffic. As to passenger traffic, there is little doubt that in the near future at holiday times we shall see advertisements of such and such a line of passenger coaches leaving all the principal towns for destinations up to 200 or 300 miles distant, and with such developments large and good roadside hotels must also come.

Heavy motor vehicles will tend to run more and more by night, not only because of the clearer road but because the start at the end of one day and the arrival at the beginning of the next will be found convenient. The transport that conveys goods from a factory to the ship's side without any intermediate handling must come into increasing use. Broadly speaking, in such cases it is difficult, if not impossible, for a railroad to operate in the same time and with the same ease, partly because of the many handlings, and partly owing to the low speed of the average freight train. Door-to-door delivery by road-transport taking less time and costing less is the secret of its growing popularity. Mechanically, the rail holds the advantage, for it requires only one-third of the power to move the same tonnage on it as a well-made road. Yet in the last 20 years, while the labor cost has increased enormously, power has become relatively cheaper, and will become cheaper still. The greater power required for road-transport is therefore more than balanced. Often, for instance, a railroad involves eight handlings in the delivery of the goods from town to country against two by road.

The railroad future, therefore, seems to lie in really fast trains, averaging over 50 m.p.h.; heavy traffic in bulk, such as coal and iron; and at holiday times full trains between towns not more than 2 or 3 hr. apart, for passengers are self-sorting and self-handling freight. On the other hand, it is likely that much short-distance traffic up to, say, 100 miles, most cross-country traffic and a large proportion of the first-class traffic existing prior to the increase in railroad fares, will tend more and more to the road. Railroads already feel the draft in passenger and freight traffic, and the falling off in passenger traffic will continue and emptier trains will go on showing the effect of road competition combined with high fares.

The railroad era should be regarded only as a stage in transport development, and not as a permanent condition of affairs: the road era has just begun, and roads soon may be made of some permanent or "semi-permanent" material involving a negligible cost for upkeep. Speed limits will be abolished before long, at any rate on the open road, and when special motor-traffic roads are made the average speeds of passenger cars will equal, if not exceed, the average railroad passenger speeds. Railroads will be forced by competition into providing motor roads and conducting traffic by road as well as by rail. Some lines may be replaced by permanent roads. Overhead and underground roads are bound to be made in great cities, the streets of which cannot possibly carry the traffic, of even a few years hence, for to widen these streets is architecturally difficult and costly.

[1] From a paper read before the Institute of Transport (London).

Non-Injurious Ultimate-Strength Tests for Interplane Struts

By E. R. MAURER[1]

Illustrated with PHOTOGRAPHS AND CHARTS

THE two tests described are based on well-known theory and have been verified at the Forest Products Laboratory by experiment on solid struts of Sitka spruce and Douglas fir of the sections used in J-1 and DH-4 airplanes; also, to a lesser degree, on built-up veneer-covered struts and three-piece laminated hollow spruce struts. The slenderness ratio L/r for these struts ranged from 120 to 225. The first method is direct; the strut is subjected to an ordinary test for maximum load. The second method is indirect; the strut is subjected to a simple bending test to obtain certain data, which are used to calculate the ultimate strength.

The two methods are described in considerable detail inclusive of photographs, charts and a mathematical analysis of the second method. The verification of method by actual trials and the meaning of slender or Euler-class struts are described and explained, followed by a description of some simple homemade strut-testing machines.

THE object of this paper is to direct attention to two strength tests for ascertaining the carrying-capacity of airplane struts. These tests do not injure the struts, are reliable and practical, and are based on a simple and well-known theory. They have been thoroughly verified at the Forest Products Laboratory of the United States Forest Service at Madison, Wis., by experiment on solid struts of Sitka spruce and Douglas fir of the sizes used in J-1 and DH-4 airplanes, and to a lesser extent on built-up veneer-covered struts and three-piece laminated hollow spruce struts. The slenderness ratio L/r for these struts ranged from 120 to 225.

A random lot of airplane wood of any species probably varies widely in strength properties; even carefully selected lots have been found to vary greatly in strength. As examples, there are cited below 10 lots of airplane struts with their minimum and maximum breaking-strengths. These are all the lots recently tested at the Forest Products Laboratory and have been officially accepted for use in Army airplanes. Each lot was made by a single manufacturer.

Lot Number	Number of Struts	Material	Breaking-Strength, lb. Minimum	Maximum
1	20	Sitka Spruce	925	1,510
2	20	Sitka Spruce	1,610	3,055
3	11	Sitka Spruce	2,020	3,730
4	9	Sitka Spruce	3,780	5,760
5	6	Sitka Spruce	3,225	4,800
6	6	Douglas Fir	3,900	4,525
7	10	Douglas Fir	2,850	5,700
8	20	Sitka Spruce	3,880	6,250
9	11	Sitka Spruce	1,375	2,315
10	4	Douglas Fir	1,380	2,095

To provide adequately against the inferior pieces of wood that might enter into construction, the airplane engineer must design with appropriately low working stresses. The result is, of course, a heavier airplane and one which is far from being equally strong in all its parts. The ideal light and uniformly strong plane cannot be attained practically, but a long step toward it can be taken with reference to wood interplane struts by employing one of the two strength tests described on each finished strut to supplement the customary inspection for moisture, density, grain and defects. Under this plan the engineer would design with higher working stresses and depend on the additional test to insure the strength counted upon by him in his design.

[1] Consulting engineer, Forest Products Laboratory, Madison, Wis.

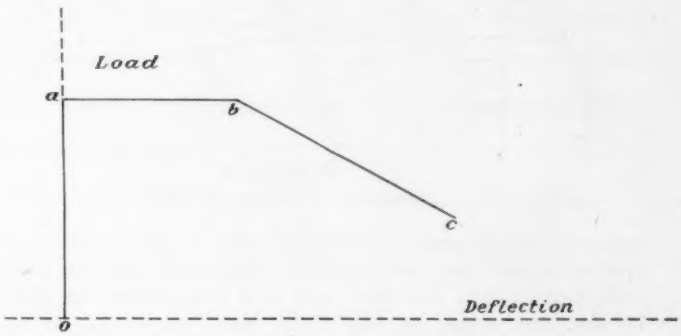


FIG. 1—DIAGRAM ILLUSTRATING THE BEHAVIOR OF A COLUMN OR STRUT ACCORDING TO EULER'S THEORY

The methods of determining the strength of individual struts, as described, can be applied only to slender or Euler-class struts, that is, struts whose slenderness ratio is higher than a certain limit, depending on species of wood and end fitting or condition of strut. For spruce and fir struts on pin or knife-edge supports this limit is about 100. Probably all interplane struts, except some stocky ones for seaplanes, fall in the Euler class. Hence the methods have wide application.

The first method is direct. It consists in actually subjecting the strut to an ordinary test for maximum load; that is, the strut is loaded gradually in a non-follow-up load testing machine until the maximum load is reached and ascertained. As theory indicates and many actual tests have proved, this test does not injure the slender strut. In the field of testing slender struts are unique, for no other structural member can be tested directly to ultimate strength without injuring it.

The second method is indirect. It consists in making a simple bending-test of the strut for certain data; then these data are used to calculate the ultimate strength of the strut. The entire method is simple and, though indirect, gives good results for slender struts.

THE DIRECT METHOD

Briefly, the Euler theory of columns is that if a slender, straight, elastic and homogeneous column be subjected to increasing axial load, it will not deflect but when a certain critical value of load is reached the column is in an unstable state and any slight deflecting force would cause a considerable deflection. The column would then remain in the deflected position under the critical load and any slight increase of that load would cause increasing deflection and finally failure. Thus the critical or Euler load is also the maximum or crippling load.

The line *oabc*, Fig. 1, represents this Eulerian strut behavior in an ordinary test, wherein the loading or moving head of the testing-machine is gradually and steadily

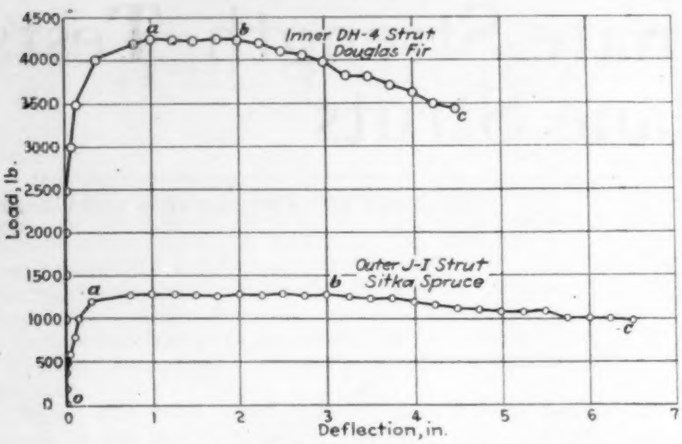


FIG. 2—LOAD-DEFLECTION CURVES OF TWO STRUTS

screwed down until failure of the strut occurs. The ordinates are the loads and the abscissas are the center deflections; thus the line *oabc* is a load-deflection graph. In the first stage, *oa*, the strut takes on a load without deflecting; in the second, *ab*, it deflects without any increase of load; in the third stage it deflects under diminishing load. The line *bc* may not be straight actually, but this is immaterial. The elastic-limit stage of the test is denoted by *b*.

According to the Euler theory, therefore, a slender, elastic, straight and homogeneous column can be loaded to its ultimate strength without injury, assuming that straining the material within its elastic limit does not injure it. The stress in the column at the stage *a* is wholly direct; at *b* mainly bending. In very slender struts the difference between these stresses is large and so the margin of safety, based on stress, of the column in the stage *a* is large.

Airplane struts are not perfectly straight and homogeneous, and their loads are not applied precisely axially. Moreover, the Euler theory is known to be imperfect. Hence, one would not expect a strut under test to behave exactly in accordance with the Euler theory. In spite of minor imperfections, however, the load-deflection graphs for slender interplane struts are decidedly Eulerian. Two such cases are described and discussed in the following paragraphs.

The lower curve in Fig. 2 is the load-deflection graph from an outer J-1 strut, whose slenderness ratio was 215. The departure of *oa* from the vertical is due to the non-axial application of the load and a lack of straightness and uniformity of the strut. But this departure is immaterial in the present connection. The important feature is *ab*, which indicates that this strut took on its maximum load much before deflecting to the elastic limit stage *b*. This load-deflection graph clearly shows that the strut behaved closely in accordance with the Euler theory, and presumably was not injured in loading up to maximum load. The greatest stress, combined compression and flexure, in this strut at the stage *a* was about 35 per cent of the greatest stress at the stage *b*.

The upper curve in Fig. 2 is the load-deflection graph for an inner DH-4 strut whose L/r was 165. In this case, too, the behavior of the strut in the test was closely Eulerian. At the stage *a* the greatest stress in the strut was about 55 per cent of the greatest stress at the stage *b*. Here, again, there was a safe test margin between the two stages.

Many other load-deflection graphs were obtained which agree more or less closely with the Euler or "theoretical" graphs. They afford good reason for believing that loading a slender interplane strut to its maximum load does not injure it. But even better reasons for the belief are given in the next paragraphs.

About 20 struts were tested repeatedly to their maximum load for the express purpose of ascertaining whether such loading injures a strut. One of the first of these, a spruce J-1 inner strut, was loaded 19 times. The first 17 runs were not carried to the elastic-limit stage and the strut was evidently not being injured. In the eighteenth run the loading was carried beyond the elastic-limit stage, 2¾-in. deflection, and in the nineteenth that strut failed, as was expected, to stand up to previous maximum loads. Eight other J-1 struts with an L/r ratio of from 185 to 225 were loaded repeatedly to their maximum load without any apparent injury.

For further confirmation, six inner DH-4 struts having an L/r value of about 165 were loaded repeatedly under more favorable testing conditions. The load-deflection graphs for tests of two of these struts are shown in Figs. 3 and 4. It will be noted that the maximum loads in the successive runs, three in the case of the Douglas-fir strut of Fig. 3 and six for the Sitka-spruce strut in Fig. 4, were practically equal. Tests of the other four struts gave the same maximum load in the successive runs.

Routine tests have been made on about 750 interplane struts, mainly of Sitka spruce and Douglas fir for J-1 and DH-4 airplanes. A few tests were made on bakelized, canvas-covered Sitka spruce, taped Sitka-spruce and

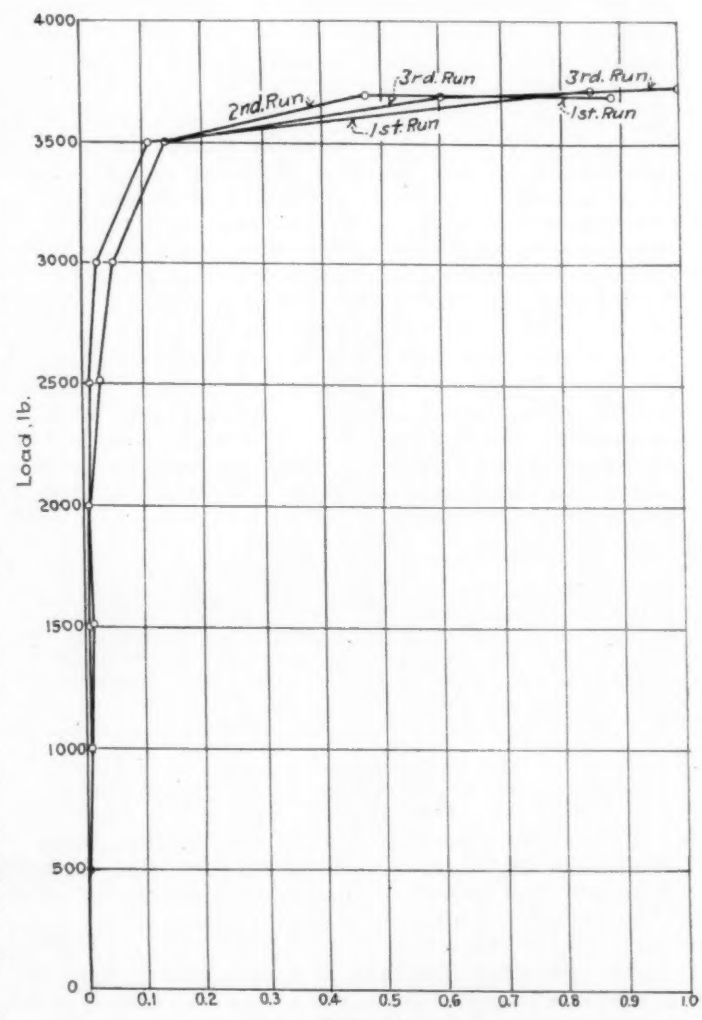


FIG. 3—LOAD-DEFLECTION CURVES FOR A DOUGLAS-FIR INTERPLANE STRUT

Douglas-fir struts, and built-up struts with yellow-birch veneer-covering and Sitka-spruce reinforcement. Most of these struts were subjected to their maximum load two or more times. Successive applications of load invariably gave about the same maximum load as the first. The relatively small differences are ascribable to slipping of the fittings or supports or to errors involved in rapid testing. When knife-edge supports were used, the agreement was always very good.

In making this test care should be taken to stop it promptly after reaching the maximum load, to reduce

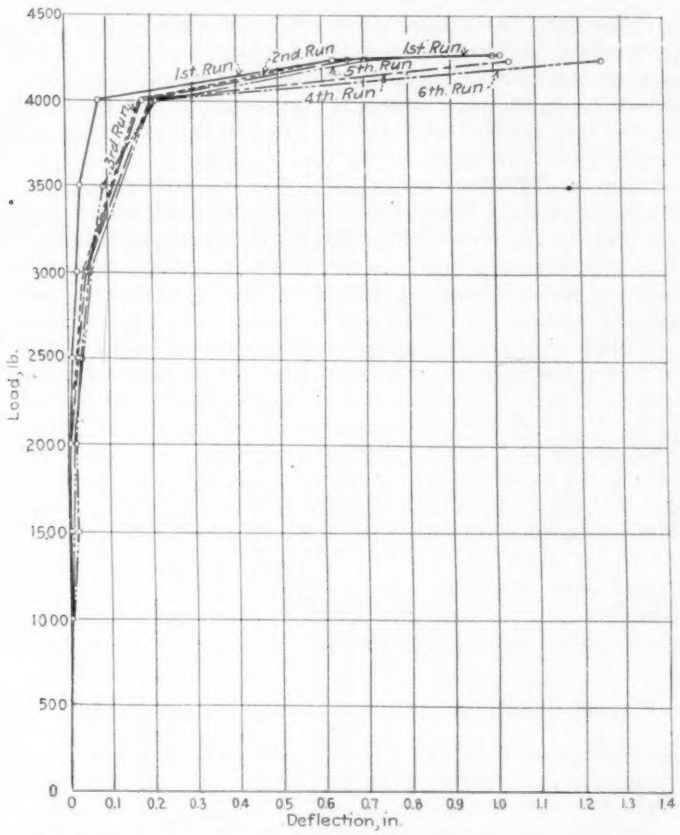


FIG. 4—LOAD-DEFLECTION CURVES FOR AN INTERPLANE STRUT OF SITKA SPRUCE

the likelihood of injuring the strut. With very slender struts this caution is not important because the elastic-limit stage comes long after the maximum load is first reached, as already explained. An experienced operator with a suitable sensitive testing-machine can easily catch the maximum-load stage promptly by paying careful attention to the weighing beam. From the beginning of the test he keeps the beam balanced by running out the poise. When the maximum load is approached the rate of poise movement required becomes less and less, and at maximum load the poise is stationary.

Testing for the maximum load is best done with two operators, one to handle the poise and call out the loads at regular intervals and the other to read and record the deflections at the announced loads. The recording is done graphically, so that a load-deflection graph is constructed as the test progresses. This graph gives the best value of the maximum load and affords a ready comparison with the second run, which is invariably made as a check and for other information.

Strut tests should be made with knife-edge supports, since these afford better results. Supports like those used in J-1 and DH-4 airplanes involve more or less friction as the strut bends in the test, and often incur appar-

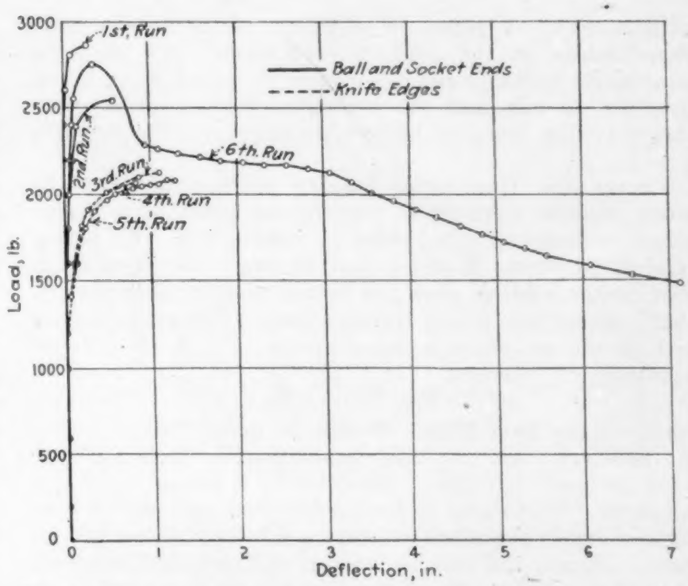


FIG. 5—LOAD-DEFLECTION CURVES OF A STRUT TESTED ON ITS OWN BALL-AND-SOCKET FITTINGS AND ALSO ON KNIFE-EDGE SUPPORTS

ent anomalies that may mislead an inexperienced operator. The graphs in Fig. 5 in the case of which runs 1, 2 and 6 were made with the strut on its own ball-and-socket fittings and runs 3, 4 and 5 with the strut on knife-edge supports, will illustrate this point. The "humps" in the graphs of runs 1, 2 and 6 are due to friction in the ball-and-socket fittings. For reasons stated in a later paragraph, curves 3, 4 and 5 are regarded as the proper indications of the strength of the strut as used in the airplanes. Fig. 6 shows load-deflection graphs of a strut tested on regular DH-4 supports. The hump h is due to a peculiarity of the fitting.

THE INDIRECT METHOD

Euler's column formula seems to be in most common use for calculating the strength of interplane struts, and the method under discussion is based mainly on that formula, which may be written

$$Q = C\pi^2 EI/L^2 \qquad (1)$$

where

C = a coefficient depending on the "end conditions" of the strut as such
E = modulus of elasticity of material
I = moment of inertia of section of support of the strut as a beam
L = the effective length of the strut or the distance between pins, balls or whatever the supporting points are
Q = total load on column

Imagine a strut supported flatwise near its ends and then subjected to a moderate cross-bending load so that the strut as a beam is not overstrained. The deflection caused by the load is given by

$$d = K(Pl^3/EI) \qquad (2)$$

where

d = deflection caused by the load P
K = a coefficient depending on the loading and manner
l = span in the beam test
P = any moderate load not overstraining the beam

For any given strut equations (1) and (2) can be combined. Combining to eliminate E and I gives the desired formula for the maximum or crippling load of the strut, namely

$$Q = CK\pi^2(l^3/L^2)(P/d) \qquad (3)$$

For struts on knife-edge supports $C = 1$. Struts on ball-and-socket and pin supports and the like in flying

airplanes are subjected to vibration which breaks down the friction at the supports and makes the supports equivalent to knife-edges. Hence it seems wise, as in practice, to calculate the ultimate strength of airplane struts on the basis of knife-edge support; that is, with $C = 1$.

Center and third-point loading were considered the most suitable methods in testing the strut as a beam; other methods were regarded as impractical. By actual trial of 12 struts it was found, contrary to expectation, that center loading gave the better results; accordingly, that loading was finally decided upon. For such loading and simple non-restraining supports, $K = 1/48$. Hence equation (3) becomes

$$Q = 0.206 (l^2/L^2)(P/d) \tag{4}$$

which is the final form. It will be noted that P and d or their ratio are the only quantities for which a test must be made to furnish the value of Q for any particular strut. This ratio is the center load per inch of deflection and is therefore a measure of the stiffness of the strut. Hence, the test is for the stiffness of the strut, which is needed in calculating the bending strength.

For struts not uniform in cross-section or composition the Euler column and the beam deflection formulas still hold; of course, appropriate mean or average values of E and I must be used in each. But are these average values in the column formula respectively equal to those in the deflection formula, permitting their cancellation or elimination? This question cannot be answered positively for all non-uniform struts, but tests of 20 tapered solid struts (10 outer and 10 inner struts for the J-1 airplane) and 5 built-up struts of the five-piece, veneer-covered type indicate that such cancellation is substantially correct. That is to say, the second method of tests, based on formula (4), was applied to these struts and gave very good results.

Verification of Method by Actual Trials

Fifty-five struts were tested by this method and, for comparison, by the first method also. To insure good results the tests by the first method were made with struts on knife-edge supports; the results are recorded in the third column of Table 1. The results by the second method are recorded in the fourth column. The percentage of difference between the two methods appears in the last column. The differences are decidedly small, and the test verification of the theory of this second method is highly satisfactory. The table includes solid and built-up fir and spruce, and uniform cross-section and tapered struts.

It will be noticed that some of the struts were tested on two spans, one of which was practically the maximum

TABLE 1—CRIPPLING LOADS FOR VARIOUS TYPES OF INTERPLANE STRUT

Strut Number	Kind and Species	Load as Measured in Column Test, Lb.	Load as Calculated from Beam Test, Lb. Span, In.		Difference Between the Two Results, Per Cent Span, In.	
Solid Struts of Uniform Section						
			52	60	52	60
DH-4	Inners					
G-41	Spruce	5,175	5,380	5,390	—4.0	—4.1
G-42	Spruce	6,350	6,420	6,530	—1.1	—2.8
G-56	Spruce	5,125	5,270	5,530	—2.8	—7.9
G-57	Spruce	4,375	4,310	4,575	+1.5	—4.6
G-64	Spruce	3,445	3,640	3,645	—5.6	—5.8
DH-4	Outers					
G-70	Fir	2,075	2,040	2,080	+1.7	—0.2
G-74	Fir	2,240	2,200	2,180	+1.8	+2.7
G-76	Fir	2,560	2,520	2,570	+1.6	—0.4
G-79	Fir	2,020	2,035	2,060	—0.7	—2.0
G-80	Fir	2,460	2,485	2,510	—1.0	—2.0
J-1	Inners					
D-1	Spruce	2,540	2,570	2,510	—1.2	+1.2
D-13	Spruce	1,800	1,750	1,820	+2.8	—1.1
D-14	Spruce	1,975	1,920	1,945	+2.8	+1.5
D-17	Spruce	1,950	1,920	2,030	+1.5	—4.1
D-2	Fir	2,170	2,220	2,200	—2.3	—1.4
J-1	Outers					
D-19	Spruce	1,450	1,425	1,430	+1.7	+1.4
D-20	Spruce	1,235	1,195	1,200	+3.2	+2.8
D-21	Spruce	1,060	1,010	1,030	+4.7	+2.8
D-7	Spruce	1,415	1,355	1,385	+4.2	+2.1
D-8	Spruce	1,390	1,385	1,360	+0.4	+2.2
Average					2.4	2.7
Solid Tapered Struts						
			64		64	
J-1	Inners					
D-1	Spruce	2,275	2,450		—7.1	
D-13	Spruce	1,700	1,720		—1.2	
D-14	Spruce	1,790	1,835		—2.5	
D-17	Spruce	1,775	1,750		+1.4	
D-19	Spruce	1,400	1,430		—2.1	
D-2	Fir	2,030	2,120		—4.4	
J-1	Outers					
D-20	Spruce	1,165	1,210		—3.9	
D-21	Spruce	1,000	1,040		—4.0	
D-7	Fir	1,300	1,330		—2.3	
D-8	Fir	1,315	1,350		—2.6	
Average					3.2	
Hollow Built-Up Struts of Uniform Section[2]						
			60		60	
J-14	All spruce and birch	4,250	4,160		+2.1	
J-15		.....	.....		.....	
J-16		4,815	4,710		+2.2	
J-17		3,760	3,600		+4.2	
J-18		3,500	3,540		—1.1	
J-19		3,425	3,440		—0.4	
Average					2.0	

Strut Number	Kind and Species	Load as Measured in Column Test, Lb.	Load as Calculated from Beam Test, Lb. Span, In.	Difference Between the Two Results, Per Cent Span, In.
Hollow Built-Up Struts				
			96	96
N-1		4,840	4,920[4]	+1.5
			4,890	+0.9
2		5,170[3]	5,380	.....
			5,550	.....
		3,700[3]	4,030	.....
			3,940	.....
4		4,930	4,900	—0.6
			5,000	+1.4
5		5,350	5,510	+3.0
			5,500	+3.0
6		5,300	5,550	+4.7
			5,560	+4.9
7		4,960	4,920	—0.8
			5,160	+4.0
8		5,100	4,860	—4.7
			5,070	—0.6
9		5,800	5,990	+3.3
			5,700	—1.7
10		4,970	4,890	—1.6
			4,800	—3.4
Average				2.5
O-1		14,200	15,000	+5.6
			15,000	+5.6
O-2		12,050[3]	13,120	.....
			13,250	.....
O-3		13,240	13,250	0.0
			13,250	0.0
O-4		12,060	12,500	+3.6
			12,860	+6.6
O-5		12,830[3]	13,680	.....
			13,300	.....
O-6		13,100	13,820	+5.5
			14,080	+7.5
O-7		12,250	13,120	+7.1
			13,120	+7.1
O-8		11,350	12,330	+8.6
			12,250	+7.9
O-9		12,500	13,750	+10.0
			13,000	+4.0
O-10		13,520[3]	14,100	.....
			14,100	.....
Average				5.6

[2]The core was a double box made of spruce covered or streamlined with two plies of spruce, the inner was longitudinal and about ⅛ in. thick, the outer circumferential and about 1/32 in. thick.

[3]Not maximum load or ultimate strength.

[4]In this group of struts the calculations were made for the strut in a normal horizontal and a reversed horizontal position.

that the strut afforded. The two were tried out to ascertain whether choice of span is important. As was expected, the choice was unimportant with struts of uniform cross-section, but with tapered struts the longer span gave the better results. Several struts were tested twice on the same span. In the second test the strut was turned over so that the side which was the upper in the first test was the lower side in the second. The values of P/d and hence of Q_2 in the two tests were practically alike in each case. As previously stated both center and third-point loadings were tried on about 12 struts and center loading gave better results.

A high degree of skill is not necessary, although for good results care should be taken about details. Both ends of the strut should be supported freely, so that bending is not hindered by them. The supports should be such that there is no doubt where the points of support are, because the exact value of span is required for use in formula (4). The bending load, P, is small compared with the maximum load for the strut as such; weighing apparatus correct to 1 or 2 lb. should be provided for measuring P. At the laboratory the bending load was applied with a 50,000-lb. testing-machine. One end of the strut, however, was supported on a small platform scale reading to quarter-pounds, which furnished accurate values of P. The deflection should be read with reference to points not on the machine but on the strut immediately over the support. For best results a single value of P/d should not be relied upon. The laboratory practice is to read both loads and deflections for a load-deflection graph; the mean straight line gives the best value of P/d for use in the formula. Of course, the loadings should not be carried to the elastic-limit stage. In the tests of J-1 and DH-4 struts deflections were run up to ½ in., really more than was necessary; all that is necessary is enough of the straight load-deflection graph to determine its slope, or P/d.

Meaning of Slender or Euler Class Strut

In the preceding discussion it is stated repeatedly that the two methods as explained hold only for slender or Euler-class struts. The question as to how slender a strut must be to put it into the Euler class will not be considered. Like most of the theory of elasticity, the theory of Euler's formula predicates stress within the elastic limit, and so the formula applies strictly only within that limit. That is $Q/A = C\pi^2 E \div (L/r)^2$ must not be greater than the elastic limit for the strut in question. Thus the formula for a particular strut holds only if the value of Q/A is equal to or less than the elastic limit of the material in compression. Again, if S denoted elastic limit, L/r must not be less than CE/S; hence $L/r = \pi\sqrt{(EC/S)}$ is the calculated lower limit of the slenderness ratio for Euler-class struts.

For Sitka-spruce struts with pin ends where $C = 1$, this formula gives a limit between 50 and 60 which is much lower than the limit shown by tests. Thus, in a paper[5] by Com. J. C. Hunsaker, U. S. N., reporting some tests, the limit is given as 70 for spruce with pinned fastenings; and the Navy Department[6] apparently sets the limit at 100 for spruce struts with pin ends.

The wide difference between the calculated and the observed limits is probably due, in part, to eccentric loading in the test of struts near the limit, or to imperfections in the strut that would have the same effect, and to lack of linear distribution of the stress on the cross-

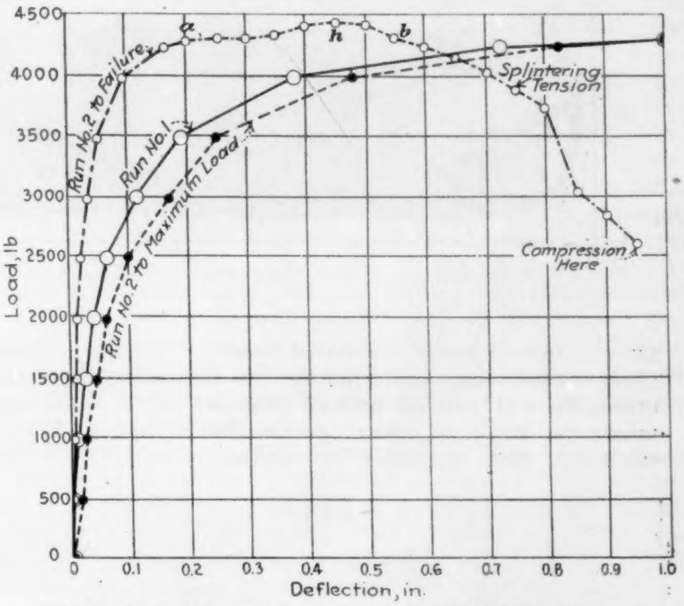


Fig. 6—Load-Deflection Curves of a Strut Tested on the Regular Supports Used in a DH-4 Airplane

sections of the strut. It may be noted that the same difference is known to exist in the case of metal struts. For example, see Fig. 7 which shows the graph of Euler's formula, for wrought-iron struts with round ends, the ordinates and abscissas being values of Q/A and L/r respectively. The yield-point stress for the material is 36,000 lb. per sq. in. Hence one might expect the Euler limit L/r to be about 85. Actually the strengths of the shorter struts are represented closely by the curve ac; that is, the Euler limit L/r is about 120 for such struts.

For additional information on the limiting value of L/r for the quality of Sitka-spruce and Douglas-fir used in airplane struts, as represented by solid DH-4 struts sent to the laboratory from time to time, three Sitka-spruce and three Douglas-fir DH-4 struts were subjected to the following special tests: Each strut, which originally had an L/r ratio of about 165, was shortened successively to L/r = 140, 120, 100, 90 and 80; and the strengths of these struts of various lengths were determined by our two methods. Table 2 gives the more im-

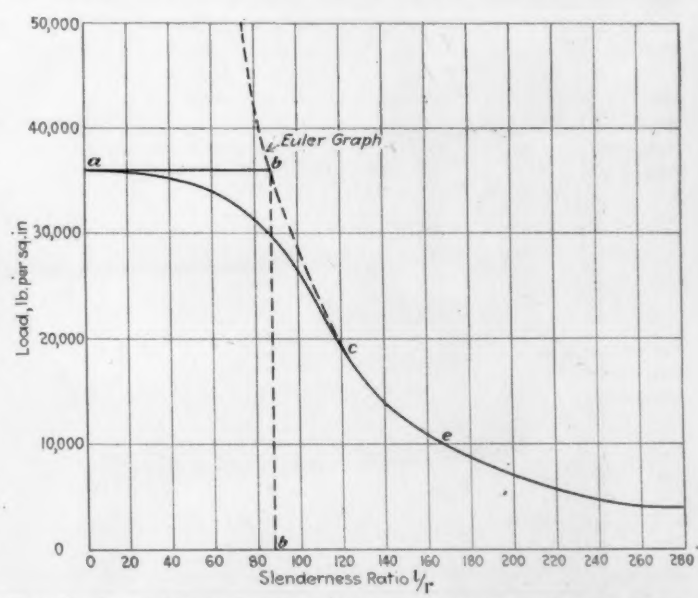


Fig. 7—Curve Giving Strength Values for Wrought-Iron Struts with Round Ends Plotted According to Euler's Formula

[5] See *Aerial Age Weekly*, Aug. 16, 1915, p. 524.

[6] See General Specifications for Airplanes issued by the Navy Department in January, 1918.

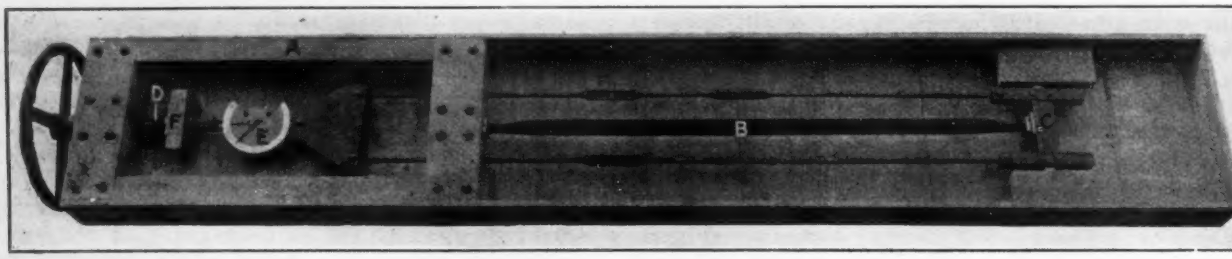


FIG. 9—ANOTHER AND MORE RECENT STRUT-TESTING MACHINE, ALSO OF THE DIRECT TYPE, DESIGNED FOR STRUT LOADS UNDER 5000 LB.

portant test data and calculated results. The last column gives the differences between the two determined ultimate strengths. It will be noticed that for strut G-96, the maximum loads as measured in the column test and calculated from the beam test agree fairly well for the

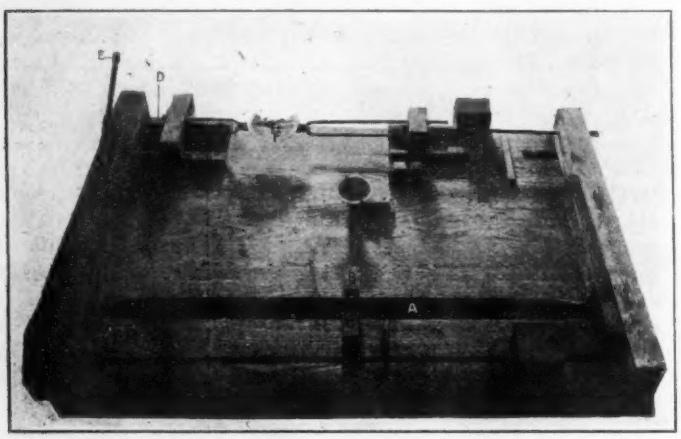


FIG. 8—STRUT-TESTING MACHINE OF THE DIRECT TYPE THAT EMPLOYS THE LEVER PRINCIPLE

successive values of L/r down to and including $L/r = 100$, but that for $L/r = 80$ the column-test load differs much from the beam-test load. Since the latter is calculated by Euler's formula, it appears that the limit value of L/r for G-96 was between 100 and 80. For G-98 the limit was between 90 and 100; for G-102, between 100 and 120; and for the three fir struts, between 80 and 90.

TABLE 2—CRIPPLING LOADS FOR STRUTS OF VARIOUS SLENDERNESS RATIOS

Strut Number	Effective Length of Strut, In.	Slenderness Ratio	Load as Measured in Column Test, Lb.	Span in Beam Test, In.	Ratio of Load to Deflection, Lb. Per In.	Load Calculated from Beam Test, Lb.	Difference in Results, Per Cent
			Spruce Struts				
G-96	65.9	166.0	4,740	64.0	400	4,960	—4.6
a	55.6	140.0	6,950	53.6	694	7,120	—2.4
b	47.6	120.0	8,895	45.6	1,104	9,520	—7.0
c	39.7	100.0	12,450	37.7	1,860	13,000	—4.4
e	31.7	80.0	18,300	29.7	4,120	22,200	—21.3
G-98	65.9	165.4	4,450	63.9	379	4,690	—5.4
a	55.6	140.0	6,625	53.6	654	6,730	—1.6
b	47.7	120.0	9,000	45.7	1,082	9,440	—4.9
c	39.8	100.0	13,200	37.8	1,850	13,100	+0.8
d	35.8	90.0	15,800	33.8	2,750	17,100	—8.2
e	31.8	80.0	17,325	29.8	3,700	20,000	—15.4
G-102	65.9	165.4	4,600	63.9	380	4,700	—2.2
a	55.6	140.0	6,250	53.6	650	6,660	—6.6
b	47.7	120.0	9,000	45.7	1,060	9,220	—2.4
c	39.8	100.0	11,750	37.8	1,860	13,200	—11.9
d	35.8	90.0	13,200	33.8	2,500	15,500	—17.5
			Fir Struts				
G-97	65.9	165.5	6,550	63.9	550	6,800	—3.8
a	55.6	140.0	9,450	53.6	957	9,840	—4.1
b	47.7	120.0	12,650	45.7	1,508	13,100	—4.3
c	39.8	100.0	18,075	37.8	2,675	19,000	—5.1
d	35.8	90.0	21,750	33.8	3,470	21,500	+1.1
e	31.8	80.0	27,300	29.8	5,700	30,800	—12.8
G-99	65.9	166.5	5,375	63.9	442	5,430	—1.0
a	55.5	140.0	7,700	53.5	774	7,920	—2.8
b	47.5	120.0	10,750	45.5	1,222	10,400	+3.3
c	39.6	100.0	14,575	37.6	2,220	15,560	—6.7
d	35.6	90.0	17,950	33.6	2,965	18,250	—1.7
e	31.6	80.0	21,700	29.6	4,090	25,900	—19.3
G-103	66.2	169.0	5,850	64.2	476	5,940	—1.5
a	54.7	140.0	9,275	52.7	892	9,000	+3.0
b	46.9	120.0	11,450	44.9	1,457	12,300	—7.4
c	39.1	100.0	17,350	37.1	2,500	16,800	+3.2
d	35.2	90.0	22,350	33.2	3,540	21,600	+3.3
e	31.2	80.0	28,000	29.2	4,550	24,000	+14.3

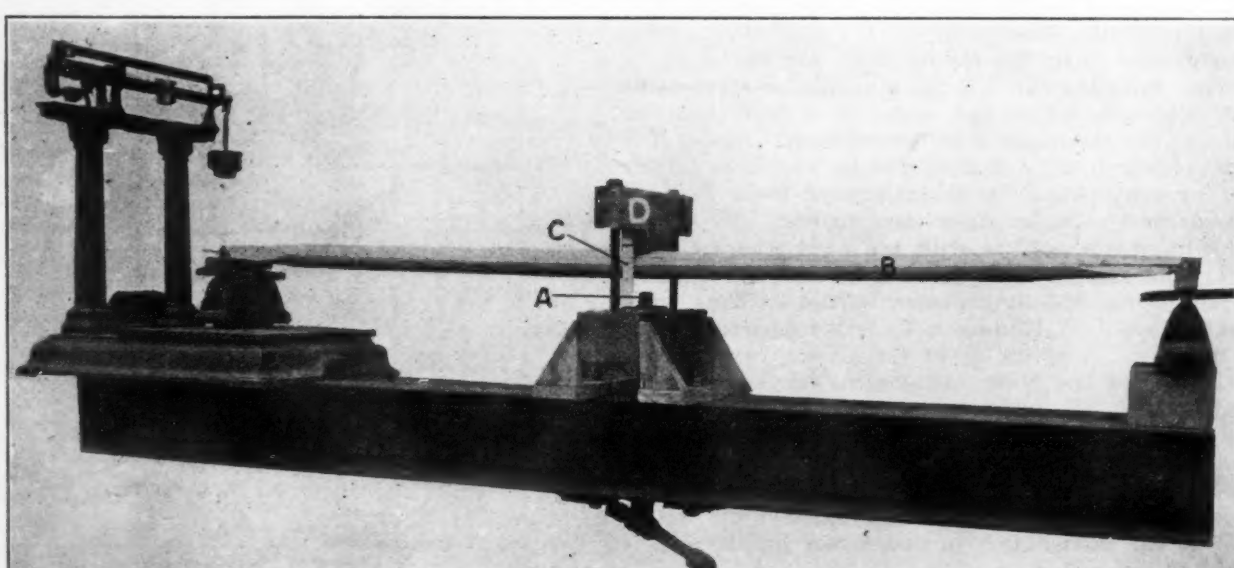


FIG. 10—A STRUT-TESTING MACHINE OF THE BEAM TYPE WHICH ALSO WAS DEVELOPED BY THE FOREST PRODUCTS LABORATORY

The conclusion, therefore, is that for such Sitka-spruce or Douglas-fir struts supported on knife-edges or the like, the Euler limits are about 100 and 90 respectively.

Some Homemade Strut-Testing Machines

The methods for determining the strengths of struts already described are not only simple but the tests required in either method can be made with a very simple machine. Three such machines have been built at the laboratory and tried out with satisfactory results.

The first machine for testing strength by the direct method, which is shown in Fig. 8, employs the lever principle and is especially suitable for large strut loads of over 5000 lb. The strut *A* which is to be tested is supported by two knife-edge fulcrums, one at each end, excessive deflection through careless operation being limited by the stops *B* and *C*. The pulling rig consists of an ordinary carpenter's bench-vise screw *D* which has eight threads to the inch. Turning the handle *E* causes a pull to be registered on the spring dynamometer *F* and this pull is transmitted by a multiplying lever to the strut as a strut load. The dial *G* is not used in making strength tests but is employed for measuring the deflection of the strut.

The second machine, Fig. 9, is of the direct-pull type without any multiplying lever and is especially suitable for strut loads under 5000 lb. It consists of a long shallow box, into one end of which a rigid and strong frame *A* is built. The strut *B* is placed for testing between one end of the frame *A* and the headpiece *C*. The load is applied to the strut by the handwheel on the screw *D*, through the spring dynamometer *E* and pulling rods to the headpiece *C*. These rods extend freely through the strut-supporting member of the frame *A* and are supported at their outer ends by the headpiece *C*. A wooden block *F* surrounds the pulling nut and prevents it from turning as well as affording an attachment for the dynamometer. Means of adjustment for different strut lengths are afforded by four turnbuckles, two in each pulling rod, and the two distance-rods connecting each pair of turnbuckles.

In the beam machine illustrated in Fig. 10 the base of the entire appliance is formed of I-beams that support the weighing scale, the loading screw *A* and one end of the strut *B*. The middle deflections of the strut are measured by the usual device consisting of a thread stretched between two points on the strut just over the supports and a suitable vertical scale *C* directly behind this thread and fixed to the strut or to the loading block *D*.

TRACTIVE RESISTANCE OF ROADS

IN connection with research on tractive resistance of roads, contemplated in the highway research program of the Committee on Economic Theory of Highway Improvement, Engineering Division, National Research Council, Major Mark L. Ireland has been assigned by the Quartermaster General of the Army to work at the Massachusetts Institute of Technology, which will be confined for the present to determining the tractive resistance of concrete-surfaced highways to 1½ and 3-ton internal-combustion-engined motor trucks. It is proposed to vary the speed, load, tire equipment, grade and curvature of highway before taking up research on other types of road surface. Major Ireland, whose address is Electrical Engineering Department, Massachusetts Institute of Technology, Cambridge 39, Mass., has requested that members of the Society furnish experimental data that they consider pertinent and valuable in the connection, on tractive resistance of roads, the manner of energy absorption in motor vehicles, gasoline consumption of various vehicles on various roads, scientific testing of automobiles, and economics of highway transportation.

STORE-DOOR DELIVERY

A GENERAL outline covering store-door delivery in our large shipping and receiving centers is as follows: The carriers when unloading freight in their terminals would be required to segregate freight on their piers for delivery to such zones as might be agreed upon among the shippers, teaming companies and carriers. The teaming companies acting either as agents for the shippers or carriers, would then load all freight for delivery within a particular shipping zone and delivery would be made direct to the consignee's door or warehouse without delay. By the elimination of delays to trucks and by full loading, the cartage charges would be materially reduced, which should prove mutually advantageous to all parties concerned.

Similar arrangements could be made to take care of outbound shipments, which could be delivered to the teaming companies under a similar arrangement, covering inbound shipments, delivery to be made as far as possible in the afternoon.—W. J. L. Banham in *The Commercial Vehicle.*

MOTORSHIPS

IT is of considerable interest to note that the motor-car industry, in which America now leads the world, developed in Europe in much the same way as the motorship industry, and it is not too much to expect that once American interests become convinced that the motorship is what the Europeans think it is, American motorship construction and operation will also lead the world.—Charles E. Lucke in *Mechanical Engineering.*

INCH SIZE ROLLER BEARINGS

IN Table 8 which appeared on page 70 of the July issue of THE JOURNAL giving the dimensions of various roller bearings for motor-truck hubs an unfortunate typographical error occurs in connection with the Bock inner bearing for spindle No. R 9. The numbers in parenthesis should have been 6379-6310 instead of 63-6310.

ACTIVITIES OF THE SECTIONS

IF the coming meetings of the Metropolitan Section are as successful as was the outing on Saturday, July 30, the Section has a busy year ahead. Apparently no financial depression had affected the New York crowd and business was evidently good enough to justify everyone taking a day off. About 150 members and guests boarded the steamer Squantum for the cruise, which comprised a run up Long Island Sound and bathing, stunts and dinner at the Chateau Laurier, City Island, New York.

The outing, not to be outdone by the Summer Meeting of the Society at West Baden and French Lick, had its technical side, most of the technique being shown by the playing of the members of the colored jazz orchestra when they were not playing, if you get what we mean; by President Beecroft's agility as an umpire; by Al Bergmann's dexterity as a dancer and the Squantum's ability to keep an even keel at the same time; by the aquaplaning by Vic Kliesrath behind his motor-boat Krazy Kat; and finally by the planning and running of the whole affair by the Chairman of the Outing Committee, Ethelbert Favary, who was disguised as an officer of the Swiss Navy.

Eleven new members of the Section were secured during the trip and their initiation proved inspiring to the Membership Committee which had been working a long time over some of them.

Aberdeen Proving Ground

The Washington, Pennsylvania and Metropolitan Sections will join with the parent Society in accepting the invitation extended by General Williams, chief of Ordnance, to visit the Aberdeen Proving Ground on Oct. 7.

The program will consist in part of

(1) Firing of small arms, including tracer bullets from machine guns
(2) Firing of mobile guns
(3) Firing of major caliber guns from 12-inch to 16-inch
(4) Demonstration of tanks, tractors and trailers
(5) Demonstration of bomb-dropping from balloons and airplanes

According to War Department regulations, admission will be limited to citizens of the United States with the exception of those manufacturing munitions for a foreign government which is at war.

Coming Professional Sessions

A preliminary announcement can now be made of the plans of a number of the Sections for the coming months.

The Dayton Section expects to hold its first fall meeting about Oct. 1. The subject will be radiation and will probably be treated by one of the officers of McCook Field. About Dec. 1 a paper on lubrication will be given, and in February one on all-metal airplane design.

The Indiana Section will have a paper on Chassis Design at its opening meeting of the season which is scheduled for Sept. 23.

The Metropolitan Section on Sept. 15 will give a synopsis of the papers presented at the Fuel Session of the Society held in May. Other subjects to be taken up are the factors affecting the design of rear axles for trucks, in November; the commercial development of the airplane, in December; and during the remainder of the year, chassis lubrication, power absorption from the flywheel to the road, car performance and how to obtain a definite factor representing it, and traffic problems including that of parking space.

Tentative dates for Detroit Section meetings are Sept. 23, Oct. 21, Nov. 18, Dec. 23, Feb. 24, March 24, April 28 and May 26. Subjects to be considered include

(1) Fuel Problem
 (a) A discussion of the different types of carbureters in use
 (b) Quality and distribution of gas
 (c) Piston design
 (d) Cylinder-wall surfaces from a production standpoint, including a discussion of the advantages of grinding versus draw-lapping
 (e) Lubrication systems, particularly as to proper cylinder-wall lubrication and a study of the methods for reducing the dilution of the oil-film by unburned fuel
(2) Research—A continuation of the work on this subject that was started last season
(3) Progress of Aeronautics—Commercial aviation and advances made
(4) Passenger-Car Bodies—Work of draftsmen and designers
(5) Production—The possibilities of a decreased cost of motor-car building

Although the dates have not been announced, the Mid-West Section plans to hold a series of meetings given over to the discussion of thermodynamics, principles of carburetion, combustion phenomena and the fundamental losses in internal combustion engines.

The Minneapolis Section will have sessions during the season on manifold design and fuels, tractor wheels and traction, steam power for farm tractors, road-building machinery and engineering, power cultivators and tools, engine-to-ground power absorption in tractors, and tractor publicity and demonstrations. The engineering sessions will in most cases be preceded by informal talks on non-technical topics by prominent executives.

The Pennsylvania Section will open its season with a meeting at the Torresdale Golf Club on the afternoon and evening of Thursday, Sept. 22. Sports will occupy the afternoon. After dinner there will be a brief discussion of some of the more important papers that were presented at the meeting of the Society held in May. President Beecroft has accepted an invitation to be present. In November there will be a Diesel engine and fuel meeting, in December an aviation session and in January a discussion of the Society 1922 Annual Meeting papers with the authors of several of these papers in attendance. The February session will be devoted to consideration of current business conditions, that of March to electrical equipment, and in April commercial motor transportation, truck axles and springs will be discussed. The Section year will close in May with an inspection trip to one of the nearby body-building plants and an evening session on body engineering.

GEOLOGICAL TIME

ONE of the most fundamental conceptions of geology is the vast duration of geological time. We are accustomed to count time in days, months and years, but in geology time is counted in millions of years. Estimates of the age of the earth, based on several lines of reasoning, vary from 20,000,000 to more than 1,000,000,000 years. The figure most widely accepted is 90,000,000 to 100,000,000 years. If we consider the relation of the life of an individual who attains the age of 70 to the possible age of the earth, we may, perhaps, obtain a better understanding of the time involved. Dividing 100,000,000 by 70, we obtain the quotient, 1,428,571.43. The brief career of a person of this age would have about the same relation to the career of the earth as 1 sec. has to approximately 16½ days.—F. M. Van Tuyl in *Oil News*.

Current Standardization Work

THE July 1921 issue of data sheets for the S. A. E. HANDBOOK was sent to the members during August. These sheets contained the standards revised in accordance with the recommendations of the Standard Committee printed in the July issue of THE JOURNAL, pages 55 to 74 inclusive, and adopted by letter ballot of the voting members of the Society on July 23. The complete vote on the recommendations is tabulated below. The first column gives the number of affirmative votes; the second column, the negative votes; and the third, the number of members who did not vote either way.

Subject	Yes	No	Not Voting
Clutch Release Type Thrust Ball Bearings	182	5	151
Roller-Chain Sprockets	148	2	188
Roller Chains	149	1	188
Insulated Cable	112	2	224
Electrical Equipment Nomenclature	121	4	213
Magneto Couplings	144	1	193
Carbureter Flanges, Cast-Iron Type	189	0	149
Carbureter Flanges, Two-Bolt Type	194	1	143
Disc-Clutch Flywheel Housings	191	1	146
Rating of Storage Batteries (Cancellation)	112	4	222
Head-Lamp Brackets	157	1	180
Motorcycle Head-Lamp Mounting	116	0	222
Lamp Nomenclature	164	0	174
Bases, Sockets and Connectors	155	4	179
Exhaust Pipes	188	0	150
Square Shaft Fittings	182	0	156
Universal-Joint Hubs	181	2	155
Drain-Cocks	186	1	151
Stationary-Engine Belt Speeds	92	8	238
Stationary-Engine Rating	110	1	227
Lubricator Cups	103	0	235
Stationary-Engine Crankshafts	92	6	240
Hopper Capacities	93	1	244
Motor-Truck Bodies	129	1	208
Motor-Truck Hubs	138	3	197

Of the ballots mailed to voting members, 338 valid ballots were cast or 13.5 per cent.

The recommendation of the Stationary-Engine Division for stationary-engine belt speeds was not included in the July issue of the data sheets because, in view of the reasons submitted in support of the negative votes, it is desired to give further Division consideration to the recommendation before final publication.

Axle and Wheel Standardization

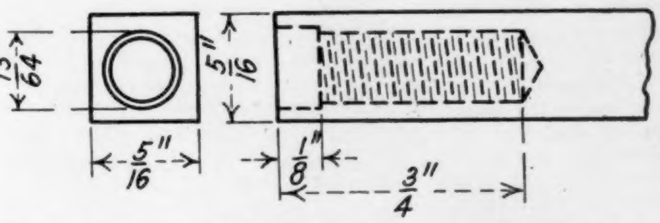
In order to make the work of the Axle and Wheel Division of most value to the axle and wheel manufacturers, a general letter has been sent out to them, requesting that they advise the Society of any additional parts that they feel the Division should undertake to standardize at the present time.

Door-fit Clearances

The Passenger-Car Body Division has tentatively recommended that the following door-fit clearances should be adopted as S. A. E. Standard for all types of body. The clearances are measured from wood-to-wood or metal-to-metal before painting.

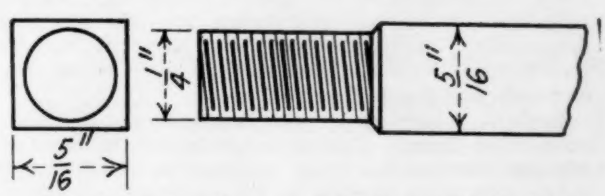
Location	Clearance, In.
Hinge Side	1/8
Lock Side	3/16
Bottom	7/32
Top	1/8
Jamb	3/16
Bead	3/32

The Passenger-Car Body Division has also tentatively recommended that door-handle squares shall be made from 5/16-in. cold-drawn key-stock as given in the accompanying illustrations.



Drill—No. 21 (0.159 in.). Counter-drill—13/64 in. Thread—No. 10 (0.189 in.)—32 U. S. F. Usable length, ⅝ in. Pitch diameter limits, 0.1713 in. min., 0.1718 in. max.
INTERNALLY-THREADED TYPE

The counter-drill has been specified for the internally-threaded type to permit filing off the end of the shank to fit the job as variations, caused by machining the door-lock pillar, require variations in the end of the shank. Tolerances of plus or minus 0.001 in. have been specified for the material as it is felt that real workmanship requires these tolerances, which have been specified by certain automobile companies for several years.



Thread—¼ in.—28 S. A. E. Usable length, ⅝ in.
EXTERNALLY-THREADED TYPE

Flexible Conduit

A meeting of the Electrical Equipment Division Subdivision on Flexible Conduit was recently held at Cleveland. After considerable discussion regarding the use of flexible conduit on automotive vehicles, B. M. Leece, chairman of the Subdivision, appointed Clarence Renshaw a committee of one to obtain information on present and desirable practice for flexible conduit and to formulate a preliminary report covering dimensions and materials.

Generator and Starting-Motor Mountings

A Subdivision of the Electrical Equipment Division has been appointed to review the present S. A. E. Standards and Recommended Practices for generator and starting-motor mountings, as several suggestions have been received in reference to extending and revising the present standards. The personnel of the Subdivision is T. L. Lee, chairman, R. G. Thompson and Ernest Wooler.

Lamp Glasses

It has been suggested that the present S. A. E. Standard for head-lamp glasses or lenses be extended to specify the dimensions of lugs to prevent the glasses from turning in the head-lamps. This subject will be considered at the next meeting of the Lighting Division.

Passenger-Car Body Nomenclature

George J. Mercer, Chairman of the Subdivision on Body Nomenclature, has submitted a report to the Passenger-Car Body Division. It is intended that by the time the names have been revised and adopted by the Division drawings will be ready to accompany each model described. The report follows:

Roadster—A small open-type body, with one fixed cross seat for two passengers and a space or compartment at the rear for carrying luggage. Emergency seats are sometimes made to fold into the luggage com-

partment or are located on the running-boards. Usually this body has two doors. The conventional type has a folding roadster top with emergency side-curtains that are removable.

Sometimes the roadster is made with a seating capacity for three or four on two fixed cross seats and is known as a four-passenger roadster. In this type the doors open directly to the front seats and access to the rear cross seat is obtained by an aisle that divides the front seats.

Touring—An open-type body with two fixed cross seats for four or five passengers. It may have folding emergency seats in the tonneau for two additional passengers. The body has four doors and a folding touring top with emergency side-curtains that are removable.

Touring-Phaeton—When a passenger-car builder markets two sizes of touring car body on the same size chassis, the smaller model is sometimes called a phaeton. Generally one is called a seven-passenger body and the other a five-passenger body.

Sometimes the touring model is made with the front seats separated by an aisle of sufficient width to permit a person to pass between them. This type is sometimes called the salon-touring body.

Sedan—An enclosed single-compartment body with two fixed cross seats for four or five passengers. Sometimes the front seats are divided by an aisle and the body has folding emergency-seats for two additional passengers. This type of body may have two, three or four doors. There are three movable glass windows on each side and the roof is fixed.

Berline—A body of the same description as the sedan, except that there is a partition at the rear of the driving seat that makes it an enclosed two-compartment body. One window glass in the partition is made so as to move vertically or horizontally.

Coupe—An enclosed single-compartment body with one fixed cross seat. This seat may be straight and seat two, or staggered and seat three. With the latter arrangement a collapsible seat may be placed by the side of the driving seat, thus making it a four-passenger body. There are two doors, two movable glass windows on each side and the roof is fixed.

Sometimes the seating plan is to have the two-passenger portion of the cross seat set back so that the passengers sit back of the driver's seat. The fourth seat is then usually a collapsible seat, but set back further.

Coupelet—A body of the same description as the coupe except that the top is collapsible. There is only one movable glass window on each side. The rear quarters and back above the belt and the roof are covered with leather or imitation leather. The front pillars or windshield standards are fixed. The doors are of the landau type with flappers or folding upper frames and the top back of the front pillars is entirely collapsible.

Limousine—A partially enclosed body with a fixed roof that extends the full length of the body and is attached at the front to the windshield standards. Only the rear section of the body forward to the partition at the rear of the driving seat is fully enclosed; forward of this point the sides are enclosed only from approximately the belt downward. There are two low doors and one fixed cross seat for two in the forward section. In the rear section there is one fixed cross seat for two or three and sometimes two emergency collapsible seats. There are two doors in the rear section and two movable glass windows on each side.

Brougham—A body of the same general description as the limousine, except that the fixed roof extends over only that section of the body that is entirely enclosed.

The brougham as originally used on carriages had only one movable glass window on each side. Occasionally, it is made this way for passenger cars.

Landau and landaulet bodies have been superseded or used in combination with other types, because the true landau does not have a sufficient body length for passenger-car use. The coupelet is a landaulet with the exception that the manner of folding the portion of the roof rail over the door is made with a different hinging arrangement and the front pillars are fixed. The cabriolet has superseded the landau, but it is different in that the falling-pillar hinge has a large swinging radius and therefore permits the rear section to be large enough for present uses. Both the coupelet and the cabriolet make use of the landau type of door, whereas the combinations, limousine-landaulet and brougham-landaulet, make use of the landau falling-pillar hinge, but do not use the landau type of door.

Limousine-Landaulet—A body of the same general description as the limousine, except that the top back of the rear doors is collapsible. Forward of these doors the roof is fixed and the windows are the same in number as for the limousine. The rear quarters and back above the belt and the roof are covered with leather or imitation leather.

Brougham-Landaulet—This type of body has the same relation to the brougham that the limousine-landaulet has to the limousine.

Cabriolet—A partially enclosed body, the two sections being the same as with the brougham. The roof and the pillars forming the partition are fully collapsible. The rear doors are of the landau type with either flappers or folding upper sections. There is one movable glass window on each side. The rear falling-pillar hinge has its center located far enough back from the face of the pillar to throw the top when falling back of the rear bar and the parting-line from the pillar face to the hinge center is generally a segment of an oval and shows plainly. The rear quarters and back above the belt and the roof are covered with leather or imitation leather and the back and side roof corners in the conventional design have a larger radius than in other types of closed body. The interior seating arrangements are for two or three passengers on one fixed cross seat and small folding seats on the partition for two facing back.

Town Car—This term is used for body types that are designed particularly for local use such as for shopping in cities and applies to chauffeur-driven cars only.

Passenger-Car Front-Axle Hubs

A Subdivision of the Axle and Wheel Division has been appointed to formulate a preliminary recommendation for front-axle hubs for passenger cars. The personnel of the Subdivision, known as the Passenger-Car Front-Axle Hubs Subdivision, is C. T. Myers, chairman, G. L. Lavery, R. B. Mudge, O. J. Rohde, F. W. Gurney, T. V. Buckwalter, A. M. Laycock and A. L. Putnam.

Protective Automobile Bumpers

The present S. A. E. Standard for protective bumpers for the front or rear of passenger-cars, page C55, S. A. E. Handbook, specifies a height from the ground to the center of the bumper face, definite overall lengths and a minimum vertical depth of the face.

It was recently suggested that the Society should undertake the standardization of the bumper brackets to permit interchangeability of bumpers or, what is more important, permit mounting bumpers without injury to the passenger-car frame or body. This subject was referred to the Parts and Fittings Division by the Council, a Subdivision appointed and, at the request of the Subdivision chairman, a general letter sent out to passenger-car builders asking their comment as to the feasibility of standardizing a plain bolted-on connection for the conventional type of passenger-car with a pressed-steel frame.

The replies to these circular letters indicate that the passenger-car builders are very much in favor of such standardization and the Subdivision plans to take immediate steps in formulating a recommendation.

Rating of Storage Batteries for Farm Electric Lighting Plants

One of the most vexing problems that has come before a Division of the Standards Committee is that of formulating a suitable standard method of rating electric storage batteries such as are used in connection with isolated electric lighting plants. After a somewhat protracted consideration of the subject at the request of interests in this branch of the automotive industries, a standard was adopted by the Society in August, 1919, which was published in the S. A. E. Handbook as follows:

> The standard battery rating shall be established at a standard (initial) temperature of 80 deg. fahr.
>
> The rated capacity of storage batteries shall be based on a final voltage of not less than 1.75 volts per cell for lead-acid batteries.
>
> The period of elapsed time at which the rated ampere-hour capacity is available shall be definitely stated.
>
> In rating batteries the maximum available capacity that can be obtained intermittently or over prolonged discharge periods shall be limited to that obtainable over a period of 72 hr.
>
> The standard test shall be at the rate of 1/24 of the ampere-hour capacity (72-hr. rating) of the battery for an initial period of 4 hr., followed by a 16-hr. rest, and then by two 8-hr. periods, each followed by a 16-hr. rest. After the last rest the final discharge period shall be 4 hr.
>
> All of the above is applicable to nickel-iron batteries, except the final voltage per cell, which applies to lead-acid batteries only. The short periods at the beginning and at the end of the test permit it to begin at noon of the first day and at noon of the last day.

It was thought at the time this standard was adopted that it would become generally used, but in the latter part of 1920 it was brought to the attention of the Standards Committee that the rating was not readily understood and had not proved acceptable. The matter was consequently again taken under consideration by the Isolated Electric Lighting Plant Division and at meetings held early this year a proposed new rating was recommended, which read:

SECTION 1

> The Isolated Electric Lighting Plant Division recommends that the present S. A. E. Standard "Rating of Storage Batteries" printed on page B37, Vol. I, S. A. E. Handbook, be cancelled.

SECTION 2

> Storage batteries for farm light and power purposes shall be rated in terms of the number of hours discharge capacity at a constant rate corresponding to 300 [*200*] watts, or fifteen [*ten*] 20-watt lamps.
>
> In determining isolated electric light and powerplant battery ratings, manufacturers shall conform with the following conditions:
>
> (1) The normal range of specific gravity which is recommended by the battery manufacturers for the batteries in service shall be used during tests.
>
> (2) Battery ratings shall be established at an initial temperature of cells not to exceed 80 deg. fahr.
>
> (3) The watts at which the rating of lead batteries is determined shall be based on a normal voltage of 2 volts per cell. The final voltage on continuous discharge shall not be less than 1.75 volts per cell.
>
> (4) The batteries to be tested shall not be charged more than 120 per cent (in ampere-hours) of the last previous discharge.
>
> (5) The resultant test shall indicate the number of hours of service lead-acid batteries will give when discharged at a constant rate corresponding to 300 [*200*] watts.
>
> [(*6*) *At 200 watts, 32 volts, the constant discharge rate shall be 6.25 amp.*]

In Section 2 the items included in the brackets were changes in the Division's recommendation which were requested at a meeting of the Farm Lighting Plant Section of the Gas Engine and Farm Power Association held in Chicago shortly after the meeting of the Division.

At the Standards Committee meeting in West Baden on May 24, Section 1 of the Division's recommendation was approved, and the standard adopted in August, 1919, has been cancelled. Section 2 of the recommendation was, however, referred back for further consideration by the Division and the lighting plant industry. Following the action taken at the Standards Committee meeting a historical review of the subject and the suggestions that had been received by the Society as to what would be an acceptable rating were sent to all members of the Division and most of the companies manufacturing plants or batteries which are not represented on the Division. A general meeting was then arranged for in Chicago on July 28, for the purpose of again endeavoring to formulate a recommendation for a standard that would be practical and receive, if possible, unanimous approval from the manufacturers. Those in attendance were

[1]William A. Biesmann, General Battery & Supply Co., Chicago.
[1]W. J. Burchill, Fairbanks, Morse & Co., Chicago.
L. F. Burger, International Harvester Co., Chicago.
R. S. Burnett, standards manager, Society of Automotive Engineers, New York City.
W. A. Chryst, vice-chairman, Standards Committee, Dayton Engineering Laboratories Co., Dayton, Ohio.
G. M. Gardner, Globe Electric Co., Milwaukee.
[1]E. H. Harsher, D.-G. Storage Battery Co., Chicago.
L. W. Heath, Litscher-Lite Corporation, Grand Rapids, Mich.
[1]P. B. Hyde, General Battery & Supply Co., Chicago.
L. S. Keilholtz, chairman of the Division, Delco Light Co., Dayton, Ohio.
J. B. Livingston, Eagle Picher Lead Co., Cleveland.
[1]A. V. Morris, Electric Storage Battery Co., Philadelphia.
[2]J. N. Naiden, Prest-O-Lite Co., Inc., Indianapolis.
E. B. Newill, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
[1]E. D. West, Fairbanks, Morse & Co., Chicago.
[1]Lloyd Yost, Fairbanks, Morse & Co., Chicago.

[1]Non-member of the Division.
[2]Non-member of the Division representing I. M. Noble, member of Storage Battery Division of Standards Committee.

Discussion at the meeting related largely to what had already been done by the members of the Division to formulate a suitable standard for commercial use that could be as readily understood and used by purchasers of these lighting plants as by the manufacturers, and the efforts made by the Division members to secure unanimous agreement to such a recommendation. More or less division of opinion among the manufacturers has been evident as to what a standard rating should be, but in carrying forward the work it has been the expressed purpose of the Division to come to as nearly unanimous agreement as possible. Since it does not at this time appear possible to come to a unanimous conclusion, it is believed that a recommendation that would be approved by a large majority of the plant manufacturers should be adopted. After considerable discussion in detail as to methods of rating and the comparative results of ratings for different types of lead-acid storage batteries, it was, upon motion of Mr. West, and the second of Mr. Newill, recommended, with 10 of those present voting, two dissenting votes being cast, one by a lighting-plant manufacturing company representative and the other by a representative of a battery manufacturing company, that the Isolated Electric Lighting Plant Division report to the Standards Committee the following method of rating farm lighting plant batteries for adoption as standard by the S. A. E.:

> The standard rating of capacity for lead-acid storage-batteries for use with isolated or farm electric lighting and power plants shall be expressed in terms of watt-hours based on a continuous 8-hr. discharge test at a nominal voltage of 2 volts per cell, the discharge not to be carried beyond a terminal voltage of less than 1.75 volts per cell. The initial temperature of the battery electrolyte on test shall not be more than 80 deg. fahr.

There was some discussion in connection with a proposal to have a double rating; one based on the former standard

72-hr. intermittent rating and the other as recommended above, but this did not meet with approval. After checking the proposed new rating to specific sizes of battery to illustrate its application in practice and further remarks in connection with the attitude that will probably be taken by manufacturers on its adoption, the meeting adjourned.

As there was not a quorum of the Division present, the new proposal will be submitted to a letter ballot of the Division and by correspondence to all the lighting-plant and battery manufacturers for approval or constructive criticism before it is reported to the Standards Committee and Society meetings next January. It was desired by those present at the meeting in Chicago on July 28 that the recommendation be given wide publication so that there will be general knowledge as to what the Division is trying to accomplish and manufacturers interested in the subject given an ample opportunity to participate in the establishment of such a standard rating. The Division requests that manufacturers of plants and batteries transmit by letter to the office of the Society their approval of the action taken and advices of their intention to adopt this rating, or their reasons for not approving it. In this way, the Division will have a direct means of knowing the sentiment of the whole industry and can be guided accordingly.

Taper Fittings With Plain or Slotted Nuts

The Parts and Fittings Division has recommended that the S. A. E. Standard for Taper Fittings With Plain or Slotted Nuts, page C14, S. A. E. Handbook, be revised by the addition of a footnote reading

> The center-line of the cotter-pin hole shall be 90 deg. from the position of the keyway as shown in the drawing

The addition of this note, which definitely specifies the location of the cotter-pin hole, will avoid any possible danger of question arising as to its location. At the present time this location is only shown in the drawing illustrating the standard.

Timer-Distributor Mountings

The present S. A. E. Type B Distributor Mounting, page B16, S. A. E. Handbook, specifies that the distance from the end of the tongue of the coupling to the end of the distributor body shall vary to suit conditions. It has recently been suggested that this distance should be definitely specified and that ⅞ in. would probably be in accordance with present practice.

This subject was discussed at the last meeting of the Electrical Equipment Division, but no definite action was taken as it was desired to base Division action on the consensus of opinion of the electrical equipment and engine manufacturers. A general letter was sent out and the information obtained turned over to W. A. Chryst, who was appointed a Subdivision of one to review the information and submit a recommendation for consideration at the next meeting of the Division.

AMERICAN CAR WINS GRAND PRIX

THE automotive engineers of this country cannot refrain from feeling rather jubilant over the recent victory of an American car and driver in the French Grand Prix at Le Mans. In accomplishing this feat Jimmy Murphy attained an average speed of 78.1 m.p.h. with his Duesenberg car over a course that is reported as very rough in spots, includes three right-angle turns and one turn whose included angle is 30 deg. Thirteen cars started in the race; four Duesenberg eights represented the United States, four Ballots carried the French colors, and four Talbots and a Mathis appeared for England. Out of these 13 starters 11 were equipped with 3-litre straight-eight engines. This fact is of engineering interest since it further defines the trend, first evidenced at Indianapolis, toward this engine type for racing work.

The engine of the winning car has eight cylinders 2½x4⅝ in. cast in a single straight block integral with the upper half of the crankcase. There are two exhaust-valves and one inlet-valve in each cylinder, operated by an overhead camshaft and mounted in a detachable head. The engine is shorter than most eight-in-line engines since the crankshaft is mounted on only three bearings. It is reported that these engines are capable of running as high as 5000 r.p.m. and that the power peak is reached at 4225 r.p.m. Two carbureters are used each serving a group of four cylinders.

The braking system is the outstanding feature of the chassis and proved advantageous on this difficult course. Brakes are fitted to all four wheels and are operated by hydraulic pressure which is transmitted through flexible tubing to the brake-actuating mechanism. A three-speed transmission is employed with central control.

This is the only American victory in the series of Grand Prix races, the first of which was run in 1906. Previous attempts have been made by the designers of this country to surpass the efforts of the Continental engineers and the ultimate success of the group of men who designed and built the cars and financed this recent invasion is viewed with warranted pride by all in the industry.

THE QUANTITY THEORY OF MONEY

THE amount of money in circulation has no direct effect on prices, but indirectly it has an enormous effect, since business cannot be transacted without money. In the same way neither can houses be built without materials and tools, and yet the mere existence of these latter will not bring about an era of building by their mere plentifulness unless all the other requisites are present. Moreover, an abundance of money and of credit, especially of credit, which is an entirely different thing from money, usually leads to speculation, which creates an artificial and temporary demand that for the time being puts up prices. This is the indirect effect. A still more convincing proof of the part money really plays is found in some European countries where there is apparently an endless volume of currency, of a depreciated type, and yet prices are falling. From now on, for a time at least, we shall probably see a decreasing volume of currency, not as a cause, but as an accompaniment and consequence of falling prices, since not so much money will be needed in the conduct of business, and Federal Reserve notes will be retired automatically from circulation so that there can be the necessary adjustment of supply and demand.—A. W. Douglas in *Administration.*

Publications of Interest *to* S. A. E. Members

In this column are given brief items regarding technical books and publications on automotive subjects. As a general rule, no attempt is made to give an exhaustive review of the books, the purpose of this section of THE JOURNAL being rather to indicate from time to time what literature relating to the automotive industry has been published with a short statement of the contents.

STANDARDS FOR TESTING WELDS. American Welding Society Bulletin No. 1. Published by the American Welding Society, 33 West Thirty-ninth Street, New York. 16 pages.

The chief difference between testing a specimen of steel that includes a welded joint and testing an ordinary specimen is the non-homogeniety of the welded specimen. The welded specimen has at its center, a section composed of material that usually has physical, chemical and metallurgical characteristics distinctly different from the adjoining metal. Furthermore, the section of the added metal is more or less irregular in shape and of variable size. Consequently the procedure prescribed for testing ordinary specimens is not applicable to those containing welded joints. Although more thorough research work in this field may develop more satisfactory standards for tests of welds, the need for some immediate standards is so great that the universal use of these specifications is urged upon all those who have to do with the testing work in this field.

REPORT ON 170-HP. ABC WASP RADIAL AERONAUTICAL ENGINE. Air Service Information Circular Vol. II, No. 167. Published by the Chief of Air Service, Washington. 23 pages.

This report which illustrates and describes the ABC Wasp engine of British construction, includes also weight, dimensional and performance data. The performance with regard to power, economy and cooling was the best obtained by the engineering division of the Air Service on any stationary radial air-cooled engine of over 100 hp.

AERODYNAMIC CHARACTERISTICS OF AIRFOILS. National Advisory Committee for Aeronautics Report No. 93. Published by the National Advisory Committee for Aeronautics, Washington. 81 pages.

This report brings together the investigations of aerodynamic laboratories of this country and Europe upon the subject of airfoils suitable for use as lifting or control surfaces on aircraft. The data have been arranged so as to be of the most use to designing engineers and for purposes of general reference. Curves are presented from which the airfoil coefficients can be read with sufficient accuracy for design purposes. The dimensions of the profile of each section are given at various stations along the chord in per cent of the chord. In order that the designer can select easily a wing section suited to a particular type of machine, four index charts are given that classify the wings according to their aerodynamic and structural properties.

DEFLECTION OF BEAMS OF NON-UNIFORM SECTION. Air Service Information Circular Volume III, No. 213. Published by the Chief of Air Service, Washington. 10 pages.

This report explains and illustrates a graphical and analytical method of calculating the deflection of beams of non-uniform section. The method is based on the familiar area-moment theorem and is applicable to many structural design problems in automotive work such as frame side members and airplane spars.

MEASUREMENT OF IMPACT OF MOTOR TRUCKS ON ROADS. By Earl B. Smith. Paper read before the American Society for Testing Materials, 1315 Spruce Street, Philadelphia. 8 pages.

The author describes and compares two methods developed in the laboratories of the Bureau of Public Roads for measuring the road impact of motor-truck wheels. In the method designated as the "autographic method" a mechanism is provided which records the space-time curve of the vertical movement of the truck wheel. By a process of differentiation a deceleration-time curve is constructed from this and the impact force calculated. In the second or "deformation method" the impact force compresses a small copper cylinder. The resulting deformation when compared with that of a similar cylinder compressed statically serves as a measure of the impact force.

THE 300-HP. BENZ AIRCRAFT ENGINE. By Dr. A. Heller. National Advisory Committee for Aeronautics Technical Note No. 34. Published by the National Advisory Committee for Aeronautics, Washington. 17 pages.

This description, translated from the *Zeitschrift des Vereines Deutscher Ingenieure*, outlines the features of the 12-cylinder, 60-deg. V-type, 135 x 150-mm. (5.315 x 5.906-in.), Benz aircraft engine. Detail drawings show the cylinder construction, valve gear, connecting-rods, piston, oil and fuel system units and the general assembly. Performance data are not given.

AUTOMOTIVE IGNITION SYSTEMS. By E. L. Consoliver and G. I. Mitchell. Published by McGraw-Hill Book Co., New York City. 269 pages; 345 illustrations.

This volume illustrates and describes in an elementary way the principles and construction of the modern electric ignition system for automotive engines. Although intended primarily for the man who installs or repairs ignition apparatus, it should assist the automotive engineer whose knowledge of ignition systems is limited, to become familiar with their essential details and operation. Chapters are devoted to the simple principles of electricity and magnetism, storage batteries, battery-ignition systems and high and low-tension magnetos. The care and repair of ignition apparatus are treated and the means of correcting ignition troubles given.

THE DYNAMOMETER HUB FOR TESTING PROPELLERS AND ENGINES DURING FLIGHT. Translated from *Zeitschrift für Flugtechnik und Motorluftschiffahrt*. National Advisory Committee for Aeronautics Technical Note, No. 59. Published by the National Advisory Committee for Aeronautics, Washington. 18 pages.

A dynamometer hub that measures and records the torque and thrust of a propeller while in flight is described and illustrated. This was developed at Adlershof, Germany, during the war by the staff of the aeronautical laboratory. Observed results of flight tests are presented and analyzed.

EXPERIMENTAL REINFORCED PLYWOOD TRUSS RIBS. Air Service Information Circular Vol. III, No. 212. Published by Chief of Air Service, Washington. 17 pages.

This report summarizes the work that has been done by the Air Service on the development of reinforced plywood truss ribs for airplane wings and compares this type of rib with other types. The comparisons show that the reinforced plywood truss type of rib construction is probably superior to any other type of wood construction so far developed. The simplicity and low production cost of this rib are its most essential features, although it is very stiff and rigid in comparison with other types.

CAMS, ELEMENTARY AND ADVANCED. By Franklin DeR. Furman. Published by John Wiley & Sons, New York City. 234 pages; 182 illustrations.

The principal interest of the automotive engineer in this book lies in its treatment of the several types of cams commonly used in the operating mechanism of poppet valves. Velocity and acceleration diagrams are constructed to show

the characteristic action of cams having different forms of base curves. Study of the diagrams enables the designer to select the type best suited for his particular need since comparison readily shows which form is best adapted for gravity, spring or positive return, and which is best for slow or fast velocities at various points in the stroke. The major part of the book is devoted to this discussion of cams for the conversion of rotary to vertical lift motion, although other miscellaneous actions and constructions are described, including the one where a rocker arm is interposed between the cam and lifter.

CALIBRATION OF CARBURETER JET FLOW. Air Service Information Circular Vol. III, No. 243. Published by the Chief of Air Service, Washington. 19 pages.

It has been recognized for some time that many of the discrepancies in carbureter performance can be traced to the use of improperly sized jets and more especially to the variation in flow of jets of the same nominal orifice size and shape. The object of this test was to determine the extent of this latter variation and obtain standard flow calibration curves for certain airplane carbureter jets. The test showed that a large variation in flow exists in carbureter jets of the same nominal orifice size, especially those soldered and drilled, and it is recommended therefore that all jets be calibrated by the use of a flow meter.

INVESTIGATION OF JUNKER BIPLANE WINGS. Air Service Information Circular Vol. III, No. 230. Published by the Chief of Air Service, Washington. 15 pages.

This report covers an exhaustive investigation of the wing and control plane structures of the Junker internally-braced monoplane. Physical properties and chemical composition of the duralumin used are given and the design and construction of the wings analyzed. It was concluded that the Junker wings are good examples of practical all-metal airplane construction. The duralumin tubing had an average ultimate tensile strength of 50,000 lb. per sq. in. and contained 94.6 per cent of aluminum, 3.34 per cent of copper, 0.81 per cent of iron and lesser quantities of silicon, magnesium and manganese.

THE ENGINEERING INDEX FOR 1920. Published by the American Society of Mechanical Engineers, New York City. 586 pages.

About 700 engineering periodicals, representing those not only of France, England and Germany, but even of Africa, India, Japan, Belgium and others, have been reviewed and indexed in the Engineering Index for 1920. The alphabetical arrangement of the 1919 Index, which marked such a decided improvement over the former group or sectional arrangement, has been retained in this new issue. The descriptive paragraphs after each reference continue to be a valuable feature because of the economy of time that can be effected in making a research study. The automotive engineering field is very well covered and numerous references are noted on carbureters, fuels, engines and production methods. Any one of the articles indexed can be purchased in photostat form from the Engineering Societies Library, 29 West 39th Street, New York City.

GASOLINE AND OTHER MOTOR FUELS. By Carleton Ellis and Joseph V. Meigs. Published by D. Van Nostrand Co., New York City. 700 pages; 206 illustrations.

The student of the engine-fuel problem will find this volume a valuable addition to his library. The major part of the book describes the different distillation and refinery methods for the production of gasoline, including the several cracking processes. The means of condensing hydrocarbons from gases for the production of casinghead gasoline are illustrated and the manufacture of benzol described. Chapters are devoted to the use of benzol, alcohol and mixed fuels in internal-combustion engines and the accepted methods for testing fuels are given. The appendices include statistical data on production and consumption, a table of chemical and physical constants for hydrocarbon gases and vapors, and a study of the production of gasoline from natural gas.

BLACK NICKEL PLATING SOLUTIONS By George B. Hogaboom, T. F. Slattery and L. B. Ham. Technologic Paper of the Bureau of Standards No. 190. Published by Government Printing Office, Washington. 9 pages.

To produce the gun-metal finish on military hardware, "black nickel" plating was frequently applied. Investigation showed that for this purpose very complicated solutions were frequently employed, and at times great difficulty was encountered in producing uniform results. This paper describes the results of a few experiments on such solutions and contains recommendations regarding the composition and conditions of operation that will yield satisfactory deposits upon brass, copper and zinc; upon brass plated with copper; and upon steel plated with copper, nickel, or zinc. This type of plating is applicable to automotive parts where a dark finish is desirable.

AIRPLANE PERFORMANCE AND DESIGN CHARTS. Prepared by the Engineering Division of the Air Service. Air Service Information Circular Vol. II, No. 183. Published by the Chief of Air Service, Washington. 23 pages.

This report describes an empirical-theoretical method of predicting from graphical charts the performance of an airplane whose weight, area, horsepower and external characteristics are known and, by corollary, a method for determining the weight and area of an airplane of given horsepower and external characteristics that is to be designed to realize a particular performance.

TRANSACTIONS OF THE SOCIETY FOR 1920

THE members will soon receive bound copies of the TRANSACTIONS of the Society for the first half of 1920. This volume has been in process for some time, having been delayed by an extended printers' strike.

The volume just completed is the largest in point of text pages and is the fifteenth to be issued by the Society. There is a total of 1083 pages exclusive of the general index, this comparing with 798 pages in Part 1, 1919, the next largest half-yearly volume.

The major part of the text matter is made up of automotive engineering papers of permanent value, most of which were contributed by members at Society and Sections meetings. There are 46 technical papers in all and they cover the several automotive fields in which the members are engaged. A classification shows that six papers relate to fuel matters, eight to cars and trucks, eight to aviation, six to engines, five to tractors, three are on marine subjects, and ten cover general subjects. Most of the papers are illustrated with drawings, photographs and curves making them especially clear and valuable to the members for reference purposes.

The report of the Standards Committee for January, 1920, occupies 65 pages. The Division reports serve as a permanent record of the progressive work done by the Standards Committee in the last half of 1919 and are accompanied in each case by the necessary tables or diagrams to illustrate the Standards or Recommended Practice as adopted.

LAST ADDRESS OF MEMBERS NEEDED

Members who contemplate changing their mail address or have already done so should be especially careful to notify the Society offices in New York City in view of the possibility of this valuable volume not reaching them.

All members who paid dues for the period covered by Part 1 1920 TRANSACTIONS are entitled to copies of it. The price of the volume to non-members is $10.

Applicants *Qualified*

The following applicants have qualified for admission to the Society between July 10 and Aug. 10, 1921. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

BANCROFT, FLOYD C. (A) technical field representative, Locomobile Co., *Bridgeport, Conn.*, (mail) 2679 Main Street.

BARTLETT, LINTON G. (M) vice-president and chief engineer, O'Connell Motor Truck Co., *Waukegan, Ill.*

BENEDICT, MAJOR CHARLES C. (S M) engineering division, Air Service, McCook Field, *Dayton, Ohio.*

BEST, HARRY A. (A) sales representative, Sheldon Axle & Spring Co., Wilkes-Barre, Pa., (mail) 4933 North Kedzie Avenue, *Chicago.*

BLAIR, ROBERT (A) aviator, Blair Flying School, Box 134, *Bellville, Ill.*

BONELL, RALPH K. (M) 636 Oakland Avenue, *Ann Arbor, Mich.*

BOONE, CAPT. MILTON O. (S M) Quartermaster Corps, (mail) *Camp Sherman, Ohio.*

CARMAN, ARTHUR G. (M) chemist and metallurgist, Franklin Die-Casting Corporation, *Syracuse, N. Y.*

CLOYD, P. C. (M) Willard Storage Battery Co., 2524 South Wabash Avenue, *Chicago.*

CONANT, DAVID J. (A) mechanical engineer and chief engineer, Western Well Works, Inc., 522 West Santa Clara Street, *San Jose, Cal.*

DARNELL, REX C. (M) assistant chief engineer, Northway Motor & Mfg. Co., *Detroit.*

DE MARINGH, ALBERT F. (A) sales engineer, Marburg Bros., Inc., New York City, (mail) 1237 Jarvis Avenue, *Chicago.*

DICHMAN, ERNEST W. (S M) aeronautical engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio.*

DOMONOSKE, ARTHUR B. (M) assistant professor of mechanical engineering, University of California, 32 Mechanics Building, *Berkeley, Cal.*

EYMAN, ERNEST E. (A) sales agent, National Malleable Castings Co., 10600 Quincy Avenue, *Cleveland.*

FULDA, RENE (F M) director, Société Française des Automobiles White, *Paris, France,* (mail) 82 Boulevard Flandrin.

HEWITT, CLARENCE C. (A) special factory representative, Tide Water Oil Co., New York City, (mail), 44 Garfield Building, *Detroit.*

HOFFMAN, MAJOR E. L. (S M) chief of equipment section, engineering division, Air Service, McCook Field, *Dayton, Ohio.*

HUENING, C. L. (A) in charge of specification division, Mitchell Motors Co., Inc., *Racine, Wis.*, (mail) care Engineering Department.

HUTCHINSON, ROLAND V. (M) designing engineer, mechanical engineering section, General Motors Research Corporation, *Dayton, Ohio,* (mail) 2000 Melrose Avenue.

INFIORATI, M. E., JR. (A) chief engineer and assistant general manager, J. N. Lapointe Co., *New London, Conn.*, (mail) 104 Ocean Avenue.

INSLEY, ROBERT (J) aeronautical mechanical engineer, engineering division, Air Service, *Dayton, Ohio,* (mail) Powerplant Laboratory, McCook Field.

JOHNSON, CHARLES B. (A) automotive specialties, Penberthy Injector Co., 1242 Holden Avenue, *Detroit.*

JONES, FRANK A. (M) superintendent, automotive department, Roxana Petroleum Corporation, D 15-Arcade Building, *St. Louis.*

KALTWASSER, C. M. (A) treasurer and general manager, Salisbury Axle Co., *Jamestown, N. Y.*

KIMBALL, EARL W. (A) vice-president and service manager, Ostendorf Motor Car Corporation, *Buffalo,* (mail) 168 Wellington Road.

KING, ALEXANDER H. (M) mechanical engineer and designer, Aeromarine Plane & Motor Co., *Keyport, N. J.*

KING, HAROLD L. (J) mechanical draftsman, Syracuse Engineering Office, Ordnance Department, *Syracuse, N. Y.*, (mail) 216 Erie Street.

KINGSTON, CHARLES T. (A) manager, John Brennan & Co., *Detroit,* (mail) 4262 Seebaldt Avenue.

LANE, F. VAN Z. (M) general maintenance manager, Hare's Motors, Inc., 16 West 61st Street, *New York City.*

LIPPERT, R. E. (A) sales engineer, Drying Systems, Inc., *Chicago,* (mail) 5530 Wayne Avenue.

LOVEN, OTTO H. (J) Park Heights Garage, *Locust Valley, N. Y.*

MCALPIN, KENNETH (A) manager, Motor Products Sales Co., *Seattle, Wash.*, (mail) 3415 East Howell Street.

MCCAULEY, J. E. A. (A) chief engineer, Hayes Wheel Co. of Canada, *Chatham, Ont., Canada,* (mail) Hotel Sanita.

MCKINNON, ERNEST C. (F M) Chloride Electrical Storage Co., Ltd., *Clifton Junction, near Manchester, England.*

MCMILLAN, NEIL, JR. (A) manager, radiator division, National Can Co., *Detroit.*

MACDONALD, LACHLAN M. (A) vice-president and general manager, Bryan Pattern & Machine Co., Bryan, Ohio, (mail) *Wauseon, Ohio.*

MIXSON, ROBERT E. (J.) aeronautical engineer, National Advisory Committee for Aeronautics, Langley Field, *Hampton, Va.*, (mail) 164 Melrose Avenue.

MOODEY, A. W. (A) engineer, Sherwin-Williams Co., 34 South Meridian Street, *Indianapolis.*

MOORE, WHITLEY B. (J.) sales engineer, Timken Roller Bearing Co., Canton, Ohio, (mail) 450 Monadnock Building, *San Francisco.*

MUHLON, EDWARD (A) 313 West 134th Street, *New York City.*

MURRAY, MAJOR MAXWELL (S M) Office of the Chief of Field Artillery, *Washington,* (mail) 1742 R Street.

NAIDEN, JAMES HENRY (M) director of laboratories, Prest-O-Lite Co., Inc., *Indianapolis.*

NATIONAL STEEL CAR CORPORATION, LTD., (Aff) *Hamilton, Ont., Canada.*
Representative:
Cartzdafner, R. E.

PARDEE, HOMER A. (A) vice-president and general manager, Halcomb Steel Co., *Syracuse, N. Y.*

PENGILLY, H. EUGENE (M) mechanical engineer, chief of motor carriage section, Ordnance Department, Washington, (mail) 112-15 St. Anns Avenue, *Richmond Hill, N. Y.*

PETERSON, GUSTAF (A) general manager of sales, Electric Alloy Steel Co., *Youngstown, Ohio.*

PETIT, HENRI (F M) engineer, Vie Automobile, Paris, (mail) 42 Rue Brancas, *Sevres (Seine et Oise) France.*

PIKE, WALTER L. (J) engineering department, Cleveland Experimental Laboratories Co., 1444 East 49th Street, *Cleveland.*

PRICHARD, LEONARD W. (E S) student, Tri-State College of Engineering, Angola, Ind., (mail) *Mount Vernon, Iowa.*

RUSSOM, DOUGLAS A. (J) development and experimental engineer, International Harvester Co., *Chicago,* (mail) 4012 West Jackson Boulevard.

SELMAN, EDWARD C. (A) member of president's technical staff, Pierce-Arrow Motor Car Co., 1695 Elmwood Avenue, *Buffalo.*

SEWARD, WALTER E. (A) technical school director, Y. M. C. A., *Canton, Ohio.*

SPEER, MODISETTE BRUCE (A) superintendent, automobile equipment service department, Westinghouse Electric & Mfg. Co., *Springfield, Mass.*, (mail) 120 East Alvord Street.

STEINBECK, PAUL W. (M) body engineer, H. H. Babcock Co., *Watertown, N. Y.*, (mail) 608 Sherman Street.

STEWART, ELLIOTT W. (M) spring engineer, William D. Gibson Co., 1800 Clybourn Avenue, *Chicago.*

TAIT, WILLIAM O., JR. (J) experimental testing engineer, International Motor Co., New York City, (mail) 476 Rossmore Avenue, *Bronxville, N. Y.*

THEARLE, ERNEST L. (M) instructor, mechanical engineering, Sibley College, Cornell University, Ithaca, N. Y., (mail) Wanakena Camp, *Pilot Knob-on-Lake George, N. Y.*

WEED, HUGH H. C. (M) first vice-president and general manager, Carter Carbureter Co., 2838 North Spring Avenue, *St. Louis.*

WHITALL, LAWRENCE W. (A) consulting engineer, Industrial Properties Corporation, *Louisville, Ky.*, (mail) 1810 South Third Street.

WERNEKEN, FRANK E. (A) secretary and treasurer, John Brennan & Co., *Detroit,* (mail) P. O. Box 683.

WILLIAMS, G. M. (M) general manager, Dayton Wright Co., *Dayton, Ohio.*

WYLIE, ARTHUR R. (M) patent attorney, Dyrenforth, Lee, Chritten & Wiles, 1508 Marquette Building, *Chicago.*

Applicants *for* Membership

The applications for membership received between June 30 and Aug. 15, 1921, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ANDERSON, F. W., vice-president and general manager, North Western Motor Co., *Eau Claire, Wis.*

BALKAM, HERBERT H., draftsman, Briscoe Motor Corporation, *Jackson, Mich.*

BERLIET, MARIUS, general manager, Societe des Automobiles, M. Berliet, *Lyons, France.*

BLAKESLEE, HERBERT, sales engineer, Splitdorf Electrical Co., *Newark, N. J.*

BUQUOR, A. P., production manager and experimental work, Compania Automoviles Anahuac de Mexico, *Indianapolis.*

CALKINS, ADDISON N., superintendent, Electric Wheel Co., *Quincy, Ill.*

CHILMAN, H. LEA, commercial transport consultant, Victoria Park, *Manchester, England.*

CORDES, JOHN, research engineer, Zenith Carburetor Co., *New York City.*

CORSON, BOLTON L., experimental engineer, H. H. Franklin Mfg. Co., *Syracuse, N. Y.*

CURTIS, PAUL R., 210 Arlington Street, *Wollaston, Mass.*

DANVILLE MALLEABLE IRON CO., *Danville, Ill.*

DESCHAMPS, RENE, works manager Minerva Motors, Ltd., *Antwerp, Belgium.*

DEWAIDE, HAL, custom body designer, Hal DeWaide Sport Cars, *Portland, Ore.*

DORIOT, GEORGES F., Doriot, Frandrin, Parant, Courbevoie, France, 14 Story Street, *Cambridge, Mass.*

ERSKINE, JAMES E., chief engineer, Perfection Engineering Products Corporation, *Jacksonville, Fla.*

FISH, MELVIN L., automotive designer, engineering office, Ordnance Department, *Syracuse, N. Y.*

FISHER, CARL HERBERT, assistant service manager, General Motors, Ltd., *London, England.*

GIRSCHIG, H., engineer, Society Dietrich a Argenteuil, *Neuilly, Seine, France.*

GRAPES, G. HAMILTON, managing director and chief engineer, Austral Motors, *Melbourne, Australia.*

HAMM, HARRY L., automotive instructor, Air Service Mechanics School, *Rantoul, Ill.*

HANLON, LAWRENCE F., sales engineer, Acme Die-Casting Corporation, *Brooklyn, N. Y.*

HEINSS, CHRISTIAN F., SR., president, Big Farmer Corporation, *Fort Madison, Iowa.*

HERRICK, EDWARD D., assistant chief engineer, Lycoming Motors Corporation, *Williamsport, Pa.*

HERON, S. D., aeronautical mechanical engineer, powerplant section, Air Service, McCook Field, *Dayton, Ohio.*

HOBART, JOHN P., JR., designer, Union Gas & Electric Co., *Cincinnati.*

HOLMES, FRANK E., head machinist, Walter M. Murphy Motors Co., *Pasadena, Cal.*

JACKSON, ELWELL R., automotive engineer, Rock Island Arsenal, *Rock Island, Ill.*

JOHNSON, FRED V., consulting engineer, Avery Co., *Peoria, Ill.*

JOHNSON, JOHN E., assistant chief draftsman, Reo Motor Car Co., *Lansing, Mich.*

KAHN, FRANK, aeronautical draftsman, Naval Aircraft Factory, *Philadelphia.*

KERSHOW, W. V., export service correspondent, J. N. Willys Export Corporation, *Toledo.*

KING, KENNETH J., student, University of Wisconsin, *Madison, Wis.*

KOPPIN, BENJAMIN L., truck designer, Erie Motor Truck Co., *Erie, Pa.*

LEAMY, J. M., power commissioner, Government of Province of Manitoba, *Winnipeg, Man., Canada.*

MCGRATH, JOHN, assistant treasurer, Eberhard Mfg. Co., *Cleveland.*

MCKINLEY, WILLIAM A., engineer, Detroit Pressed Steel Co., *Detroit.*

MACLEAN, ALLEN D., engineer, New Departure Mfg. Co., *Bristol, Conn.*

MARSHALL, LEWIS C., president, Pressure Proof Piston Ring Co., *Boston.*

MITCHELL, ALBERT F., engineer, tank, tractor and trailer division, Ordnance Department, *Washington.*

MORAN, CHARLES B., engineer, American Die & Tool Co., *Reading, Pa.*

MOTTINGER, BYRON T., chief engineer, Quaker City Rubber Co., *Wissinoming, Philadelphia, Pa.*

MURDOCK, FREDERICK R., assistant engineer, Elgin Motor Car Corporation, *Argo, Ill.*

REID, ALBERT R., chief chemist, United States Light & Heat Corporation, *Niagara Falls, N. Y.*

REINHARD, LOUIS, engineer, Geuder, Paeschke & Frey Co., *Milwaukee.*

RICE, JOHN H., mechanical draftsman, American La France Fire Engine Co., Inc., *Elmira, N. Y.*

ROCCHETTI, J., chief engineer, Manitoba Power Commission, *Winnipeg, Man., Canada.*

SCHAUFELE, WILLIAM H., JR., layout draftsman, O. Armleder Co., *Cincinnati.*

SHARPE, C. H. F., inspector, General Motors Export Co., *New York City.*

SMITH, GEORGE W., designing draftsman, Ainsworth Mfg. Co., *Detroit.*

SOCIÉTÉ ANONYME ADOLPHÉ SAURER, *Arbor, Switzerland.*

SPARK, HARRY G., sales engineer, Sparks-Withington Co., *Jackson, Mich.*

TADAICHI, SHIBATOH, chief engineer and factory manager, Japan Automobile Co., Tameike, Akasaka, *Tokio, Japan.*

TAKEO, SHIGEZO, engineer, Takeo Iron Works Co., *Kobe, Japan.*

THOKE, A. R., superintendent, Gearless Motor Corporation, 117 Flavel Street, *Pittsburgh.*

TILDEN, SYDNEY G., in charge of wholesale sales, Vandar Motor Sales Corporation, *Brooklyn, N. Y.*

WADDINGTON, CLIFFORD W., transportation supervisor, Great Atlantic & Pacific Tea Co., *Jersey City, N. J.*

WAMPLER, HOMER H., owner, Dayton Automotive Specialty Co., *Dayton, Ohio.*